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Monsanto Research Corp, Dayton, Ohio

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PREFACE

The Industrial Environmental Research Laboratory (IERL) of the U.S. Environmental Protection Agency (EPA) has the responsibility for insuring that pollution control technology is available for stationary sources to meet the requirements of the Clean Air Act, the Federal Water Pollution Control Act and solid waste legislation. If control technology is unavailable, inadequate, or uneconomical, then financial support is provided for the development of the needed control techniques for industrial and extractive process industries. The Chemical Processes Branch of the Industrial Processes Division of IERL has the responsibility for investing tax dollars in programs to develop control technology for a large number of operations (more than 500) in chemical industries.

Monsanto Research Corporation (MRC) has contracted with EPA to investigate the environmental impact of various industries which represent sources of pollution in accordance with EPA's responsibility as outlined above. Dr. Robert C. Binning serves as MRC Program Manager in this overall program entitled "Source Assessment," which includes the investigation of sources in each of four categories: combustion, organic materials, inorganic materials, and open sources. Dr. Dale A. Denny of the Industrial Processes Division at Research Triangle Park serves as EPA Project Officer. Reports prepared in this program are of three types: Source Assessment Documents, State-of-the-Art Reports, and Special Project Reports.

Source Assessment Documents contain data on emissions from specific industries. Such data are gathered from literature, government agencies, and cooperating companies. Sampling and analysis are also performed by the contractor when available information does not adequately characterize source emissions. These documents contain all of the information necessary for IERL to decide whether emissions reduction is necessary.

State-of-the-Art Reports include data on emissions from specific industries which are also gathered from literature, government agencies, and cooperating companies. However, no extensive sampling is conducted by the contractor for such industries. Results from such studies are published as State-of-the-Art Reports for potential utility by government, industry, and others having specific needs and interests.

Special projects provide specific information on services which are applicable to a number of source types or have special utility to EPA but are not part of a particular source assessment study. This special project report, "Source Assessment: Prioritization of Stationary Water Pollution Sources," was prepared to provide prioritization listings for use as aids in the selection of specific sources of water effluents for detailed assessment. This report describes the general water prioritization model, explains the manner and form of its implementation, and gives a detailed example of use. A description of hazard factors that were developed in order to prioritize specific sources is also provided. This work on sources of water effluents complements that completed earlier by MRC on the development of priority listings of sources of air pollutants.

ABSTRACT

This report provides prioritization listings for use as aids in selecting specific sources of water effluents for detailed assessment. The report describes the general water prioritization model, explains the manner and form of its implementation, and gives a detailed example of its use. Hazard factors that were developed in order to prioritize specific sources are also described.

Various industries (source types) were ranked (prioritized) on the basis of their water discharges. Solid residues were assumed to contribute to water discharges as leachates. The prioritization index for water, termed the impact factor, is based on a ratio of actual concentration to hazardous concentration. The water discharge prioritization model was applied to 262 stationary organic and inorganic sources. The source types were divided into four subcategories and prioritized: 1) petrochemicals, 2) textiles, 3) pesticides, and 4) fertilizers.

This report was submitted in partial fulfillment of Contract 68-02-1874 by Monsanto Research Corporation under the sponsorship of the U.S. Environmental Protection Agency. The report covers the period August 1976 to November 1977.

CONTENTS

Preface. iii
Abstract v
Figures. viii
Tables viii
Abbreviations and Symbols. ix

1. Introduction. 1
2. Summary 2
3. Water Prioritization Model. 7
    The mathematical model 7
    Assumptions, limitations, and caveats. 10
    Model applications 11
4. Source Prioritizations. 18
    Petrochemical source types 18
    Pesticide manufacturing source types 26
    Fertilizer manufacturing source types. 31
    Textile source types 36

References 41

Appendices

A. Derivation of a water pollution severity model. . . . 50
B. Oxygen deficit relationships. 60
C. Impact factor sample calculation. 65
D. Examples of input data sheets 82
E. Hazard factors developed for use in water prioritization. 85

Glossary 121
Conversion Factors and Metric Prefixes 123

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FIGURES

Number Page

1 Change of concentration with distance. 8

TABLES

1 Prioritization of Petrochemical Sources of Water Pollution. 2
2 Prioritization of Pesticide Sources of Water Pollution 4
3 Prioritization of Fertilizer Sources of Water Pollution 5
4 Prioritization of Textile Sources of Water Pollution . 6
5 Example of Input Data and Results for Calculation of Water Severity 16
6 List of Pollutants and Indicators of Pollution 19
7 Acrylonitrile Plant Wastewater 19
8 Average Water Discharge Characterization by Category Type 20
9 Effluent Limitations, Maximum for any One Day, for the BPCTCA 22
10 Alphabetical Listing of Petrochemical Source Types Prioritized. 23
11 Prioritization of Petrochemical Sources of Water Pollution. 24
12 Raw Wastewater Characteristics of Organic Pesticide Manufactures 27
13 Alphabetical Listing of Pesticide Source Types Prioritized. 32
14 Prioritization of Pesticide Sources of Water Pollution 32
15 Alphabetical Listing of Fertilizer Source Types Prioritized. 36
16 Prioritization of Fertilizer Sources of Water Pollution 37
17 Alphabetical Listing of Textile Source Types Prioritized. 40
18 Prioritization of Textile Sources of Water Pollution . 40

ABBREVIATIONS AND SYMBOLS

A -- fraction of river flow in mixing zones
A,B,C,D -- uncertainty levels associated with impact factor
AMZ -- aftermixing zone
AQTX -- aquatic toxicity
ar_s -- absorption retention coefficient, m^3/s
BG -- bluegill
BI_i -- biodegradability index for the ith species
BOD -- biochemical oxygen demand, mg/liter
BOD_L -- ultimate BOD, mg/liter
BOD_5 -- amount of dissolved oxygen consumed in 5 days by biological processes breaking down organic matter in an effluent
BPCTCA -- best practicable control technology currently available
BT -- brook trout
c -- pollutant concentration resulting from Outfall 1 and Outfall 2 after full dilution
C -- concentration of species in discharge, mg/liter
ca_{ij} -- ambient concentration of the ith species at the jth plant, g/m^3
cd -- concentration of pollutant in effluent, g/m^3
$\overline{cd}$ -- average discharge concentration, g/m^3
cd(t) -- discharge concentration as a function of time, g/m^3
cd_1 -- pollutant concentration in Outfall 1
cd_2 -- pollutant concentration in Outfall 2
$cd_{ij\ell}$ -- concentration of the ith species in the ℓth outfall at the jth plant, g/m^3
cf_{ij} -- fraction of the ith constituent on a dry basis in the solid waste at the jth plant, g/m^3
cf_{ijk} -- fraction of the ith constituent on a dry basis in the kth pile at the jth plant, g/m^3
c_{ij} -- final aftermixing zone concentration of ith species at jth plant
COD -- chemical oxygen demand, mg/liter
co_j -- final aftermixing zone oxygen demand concentration at jth plant
cs_j -- saturated dissolved oxygen concentration at the jth plant receiving stream, g/m^3
cs -- saturated dissolved oxygen concentration, g/m^3
c(t) -- aftermixing zone concentration as a function of time, g/m^3

ABBREVIATIONS AND SYMBOLS (continued)

D -- *Daphnia*
D_A -- actual delivered dose, g
D_H -- potentially hazardous dose, g
DO -- dissolved oxygen freshwater quality criterion, g/m^3
e -- natural base logarithm (2.72)
E_F -- effluent factor, lb/ton
E_{Fij} -- total effluent factor for the ith species at the jth plant, lb/ton
EM_i -- ecological magnification factor for the ith discharged species
E_R -- effluent rate, tons/yr
$F, F_1 \ldots F_7, F_i$ -- hazard factors
FM -- fathead minnow
F_{oj} -- hazard factor of the oxygen demand at jth plant
f_{1j} -- leachable residue fraction
f_{2ijk} -- fraction of the ith constituent on a wet basis, in the kth pile at the jth plant
G -- *Gammarus lacustris* (amphipod)
gpg -- guinea pig
HF -- harlequin fish
hmn -- human
IC_{50} -- immobilization concentration 50
ihl -- inhalation
imp -- implant
ipr -- intraperitoneal
ivg -- intravaginal
ivn -- intravenous
Iw_x -- overall water impact factor
$I'w_x$ -- weighted water impact factor
k' -- BOD_5 rate constant, $days^{-1}$
$k_1 \ldots k_5$ -- conversion factors, g/ton, g/lb, $\frac{\text{g liter}}{\text{mg gal}}$, lb/ton, s/yr
L -- wastewater loading, gal/ton
LC_{Lo} -- lethal concentration low
LC_{50} -- lethal concentration 50
LD_{Lo} -- lethal dose low
LD_{50} -- lethal dose 50
$\overline{md}$ -- average mass discharge rate, g/s
Md_{ij} -- annual discharge rate of the ith species at the jth plant, g/yr

ABBREVIATIONS AND SYMBOLS (continued)

md_{ij} -- combined mass discharge rate for the ith species at the jth plant, g/s
md(t) -- mass discharge rate as a function of time, g/s
MF -- mosquito fish
$\min|LC_{50}|$ -- lethal concentration to 50% of species most sensitive to a particular pollutant, g/m^3
mod_j -- total oxygen deficit rate at the jth plant, g/s
mos_j -- oxygen deficit rate of the solid residue leachate at the jth plant, g/s
mow_j -- oxygen deficit rate of the direct water discharges at the jth plant, g/s
ms_{ij} -- water mass discharge rate due to solid residue leaching for the ith species at the jth plant, g/s
mw_{ij} -- direct water mass discharge rate for the ith species at the jth plant, g/s
mus -- mouse
MZ -- mixing zone
m_1, m_2 -- pollutant mass discharge rate from Outfalls 1 and 2
m_3, m_4 -- pollutant mass discharge rate from Piles 1 and 2
N -- naiads (aquatic young of dragonfly, stonefly); also number of chemical species destroyed
O_F -- outfall effluent factor, lb/ton
O_{Fi} -- outfall effluent factor for the ith species, lb/ton
orl -- oral
P -- number of discharging outfalls
PC -- plant capacity, ton/yr
PC_j -- plant capacity of the jth plant, ton/yr
ppm -- parts per million
Q -- number of leachable piles
rbt -- rabbit
R_j -- rainfall rate at the jth plant, m/yr
RT -- rainbow trout
S -- severity used as a starting basis for the water prioritization model
S_A -- severity due to a pollutant in a discharge stream before dilution
S_B -- severity due to a pollutant in a mixing zone
S_C -- severity due to a pollutant after a mixing zone
scu -- subcutaneous
S_{ij} -- water severity for the ith pollutant at the jth plant
$\overline{S}_{ij}$ -- defined average severity for the ith pollutant at the jth plant

ABBREVIATIONS AND SYMBOLS (continued)

S_j -- total water severity at the jth plant (including oxygen demand severity)
skn -- skin
So_j -- oxygen deficit severity at the jth plant
So -- aftermixing zone oxygen deficit severity
S(t) -- severity as a function of time
$\overline{S}_T$ -- average severity for averaging time, T
S_{tot} -- total severity resulting from Outfall 1 and Outfall 2 after full dilution
S'_{tot} -- total severity resulting from various outfalls and leachable solid waste piles after full dilution
SW_F -- solid waste effluent factor, lb/ton
SW_{Fij} -- solid waste effluent factor for the ith species at the jth plant, lb/ton
SW_{jk} -- solid waste generation rate in the kth pile at the jth plant, g/s
S_1 -- aftermixing zone pollutant severity for Outfall 1
S_2 -- aftermixing zone pollutant severity for Outfall 2
$S'_1 \ldots S'_4$ -- aftermixing zone severity for specific outfall or leachable, solid waste pile
t -- time (t_1 and t_2 are initial and final times, respectively), s; for BOD, days
T -- reference time period; t_2-t_1; s
TC_{Lo} -- toxic concentration low
TD_{Lo} -- toxic dose low
TLV -- threshold limit value
TOC -- total organic carbon, mg/liter
TOD -- total oxygen demand, mg/liter
$TODs_{jk}$ -- total oxygen demand of the leachable, solid residue in the kth pile at the jth plant, g/m^3
$TODw_{j\ell}$ -- total oxygen demand of the direct water discharge in the ℓth outfall at the jth plant, g/m^3
vd -- effluent discharge rate, m^3/s
$\overline{vd}$ -- average discharge flow rate, m^3/s
vd_1 -- discharge flow rate of Outfall 1
vd_2 -- discharge flow rate of Outfall 2
$vd_{j\ell}$ -- discharge flow rate of the ℓth outfall at the jth plant, m^3/s
vd(t) -- discharge flow rate as a function of time, m^3/s
vr -- river flow rate, m^3/s
$\overline{vr}$ -- average river flow rate, m^3/s
vr_j -- river flow rate for the jth plant, m^3/s

ABBREVIATIONS AND SYMBOLS (continued)

$vr(t)$ -- river flow rate as a function of time, m^3/s
wf_j -- fraction of water in the solid waste at the jth plant
wf_{jk} -- fraction of water in the kth pile at the jth plant
wmh -- woman
WQC -- water quality criteria, g/m^3
$W1_{ij}$ -- ambient water quality weighting factor for ith species at the jth plant
$W2_i$ -- ecological magnification and biodegradation weighting factor for ith species
x -- specific source types
X -- annual water effluent mass loading, g/yr
X_{ij} -- total annual effluent mass loading for the ith species at the jth plant, g/yr
X_{oj} -- total annual effluent mass loading for dissolved oxygen at the jth plant, g/yr
Z -- number of plants
α and β -- dimensionless constants
Ψ_A -- actual exposure
Ψ_H -- potentially hazardous exposure

SECTION 1

INTRODUCTION

A wide variety of industrial sources discharge wastewater into the environment. In order to characterize the effluents from these sources, evaluate their environmental effects, and develop appropriate control technologies, it is desirable first to rank them in order of their potential environmental impact. In this way when limited resources are available those sources with the highest ranking can be studied first, while sources of lower priority can be addressed at a later time.

This report includes a general description of water and solid residue prioritization models used for the ranking of a selected set of industrial sources. Models are applied to selected petrochemical, agricultural, textile, and pesticide sources, and resulting relative prioritizations are presented. Computation of a relative impact factor for each discharge source provides the basis for each ranking.

No attempt in any fashion is made to relate industrial discharges to their effects on aquatic life. Based upon a set of common assumptions which are clearly identified, the model provides a ranking (within the framework of these assumptions) of stationary sources of water discharges and solid residue generation.

It must be understood that the prioritization models are at best a "first-cut" attempt at ranking numerous source types based on the potential burden they place upon the environment. In the water model, for example, potential severity is expressed as a concentration ratio of a discharged material relative to a hazard potential factor.

SECTION 2

SUMMARY

Procedures were developed whereby various industries (source types) were ranked (prioritized) on the basis of their water discharges. Solid residues were assumed to contribute to water discharges as leachates. The prioritization index for water, termed the water impact factor, is based on a ratio of estimated effluent concentration to hazardous effluent concentration and is described fully herein.

The water discharge prioritization model was applied to 262 stationary organic and inorganic sources. The source types were divided into four subcategories for ranking: 1) petrochemicals, 2) pesticides, 3) fertilizers, and 4) textiles. The resulting prioritization listings are shown in Tables 1 through 4 and discussed in detail in the report.

TABLE 1. PRIORITIZATION OF PETROCHEMICAL SOURCES OF WATER POLLUTION

SOURCE TYPE	IMPACT FACTOR[a]	CL[b]	CALC[c]
PROPYLENE OXIDE - CHLOROHYDRIN PROCESS	10,000,000,000	B	3
ADIPONITRILE	5,000,000,000	B	3
N-BUTYRALDEHYDE	5,000,000,000	C	3
PHENOL - CUMENE PROCESS	4,000,000,000	C	3
CHLOROBENZENE - CHLORINATION OF BENZENE	4,000,000,000	C	3
GLYCERIN - ALLYL ALCOHOL	4,000,000,000	C	3
GLYCERIN - EPICHLOROHYDRIN	4,000,000,000	C	3
P-DICHLOROBENZENE	3,000,000,000	C	3
ETHYLENE DICHLORIDE - ETHYLENE CHLORINATION	3,000,000,000	B	3
ETHYLENE DICHLORIDE - OXYCHLORINATION	3,000,000,000	C	3
CYCLOHEXANONE	3,000,000,000	C	3
ADIPIC ACID	3,000,000,000	C	3
VINYL CHLORIDE - ETHYLENE	3,000,000,000	C	3
CYCLOHEXANOL - FROM CYCLOHEXANE	2,000,000,000	C	3
BUTADIENE - N-BUTENE	2,000,000,000	C	3
ISOPROPANOL - PROPYLENE	2,000,000,000	C	3
PERCHLOROETHYLENE - CHLORINATION OF PROPANE	2,000,000,000	B	3
ISOOCTYL ALCOHOLS	2,000,000,000	C	3
ETHYL HEXANOL - OXO PROCESS	2,000,000,000	C	3
N-BUTYL ALCOHOL	1,000,000,000	C	3
ETHYLENE	1,000,000,000	C	2
EPICHLOROHYDRIN	1,000,000,000	C	3
CARBON TETRACHLORIDE - METHANE	1,000,000,000	C	3
ACETONE - FROM ISOPROPANOL	800,000,000	C	3
S-BUTYL ALCOHOL	800,000,000	B	3
ETHYL BENZENE - BENZENE AND MIXED XYLENES	700,000,000	B	3
BISPHENOL-A	700,000,000	B	3
CRESYLIC ACID	700,000,000	C	3
METHYL ISOBUTYL KETONE	700,000,000	C	3
O-DICHLOROBENZENE	500,000,000	C	3
METHYLENE CHLORIDE - CHLORINATION OF METHANE	500,000,000	C	3
POLYBUTENES - BUTANE	500,000,000	C	3
1,1,1-TRICHLOROETHANE - VINYL CHLORIDE CHLORINATION	400,000,000	C	3
PROPYLENE - REFINING - VIA PYROLYSIS	400,000,000	C	2
DIISOBUTYLENE	400,000,000	C	3
T-BUTYL ALCOHOL	300,000,000	C	3
BENZENE - CATALYTIC REFORMATE	300,000,000	C	2
DODECYL ALCOHOL - OXO PROCESS	300,000,000	C	3
TOLUENE - CATALYTIC REFORMING	300,000,000	C	2
NAPHTHALENE	300,000,000	C	2

(continued)

TABLE 1 (continued)

SOURCE TYPE	IMPACT FACTOR^a	CL^b	CALC^c
CARBON TETRACHLORIDE - CHLORINATION OF PROPANE	200,000,000	C	3
HEXADECYL ALCOHOL - OXO PROCESS	200,000,000	C	3
ISOBUTYLENE - EXTRACTION OF HYDROCARBONS	200,000,000	C	3
ISOBUTYRALDEHYDE	200,000,000	C	3
CARBON TETRACHLORIDE - CARBON DISULFIDE	200,000,000	C	3
ACRYLONITRILE	200,000,000	B	3
ISODECANOL - OXOPROCESS	200,000,000	D	3
METHYL ISOBUTYL CARBINOL	200,000,000	C	3
TRICHLOROETHYLENE - CHLORINATN THEN DEHYDROCHLORINATN OF EDC	100,000,000	C	3
DECYL ALCOHOL	100,000,000	C	3
XYLENES - MIXED - PETROCHEMICAL	100,000,000	C	3
ISOPRENE - DEHYDROGENEATION OF ISOAMYLENES	100,000,000	C	3
NONENE	100,000,000	C	3
PROPYLENE - FROM ETHYLENE - VIA PYROLYSIS	100,000,000	C	2
NONYLPHENOL	90,000,000	C	3
PHTHALIC ANHYDRIDE - NAPTHALENE	90,000,000	C	3
PROPYLENE - FROM ETHYLENE AND REFINING - VIA PYROLYSIS	80,000,000	C	2
ISOPENTANE	80,000,000	D	3
CYCLOHEXANE	70,000,000	C	3
BUTADIENE - ETHYLENE BY-PRODUCT	70,000,000	B	3
ISOBUTYL ALCOHOL	60,000,000	C	3
O-XYLENE	50,000,000	C	3
BENZENE - PETROCHEMICAL FEEDSTOCKS	50,000,000	C	2
CARBON BLACK - FURNACE	40,000,000	C	2
N-PENTANE	40,000,000	D	3
ACRYLAMIDE - FROM ACRYLONITRILE	40,000,000	C	3
TOLUENE - PETROCHEMICAL FEEDSTOCKS	40,000,000	C	2
ETHYL CHLORIDE - HYDROCHLORINATION OF ETHYLENE	30,000,000	C	3
PHOSGENE	30,000,000	C	3
DIMETHYL TEREPHTHALATE	30,000,000	B	3
HEPTANE	30,000,000	C	3
TRIISOBUTYLENE	30,000,000	D	3
BUTADIENE - DEHYDROGENATION OF N-BUTANE	30,000,000	D	3
HEXAMETHYLENEDIAMINE - ADIPONITRILE	30,000,000	B	3
T-BUTYL AMINE - ISOBUTYLENE	20,000,000	C	3
DIACETONE ALCOHOL - CONDENSATION	20,000,000	C	3
1,2,3-TRICHLOROPROPANE	20,000,000	C	3
GLYCERIN - ACROLEIN	10,000,000	C	3
BENZENE - COAL DERIVED	9,000,000	C	2
ETHYL BENZENE - MIXED XYLENES	9,000,000	C	3
METHYL CHLORIDE - CHLORINATION OF METHANE	8,000,000	C	3
HEXAMETHYLENEDIAMINE - AMMONOLYSIS OF 1,6-HEXANEDIOL	7,000,000	C	3
TEREPHTHALIC ACID	6,000,000	B	3
STYRENE	6,000,000	B	3
TRICHLOROETHYLENE - CHLORINATION OF ACETYLENE	6,000,000	C	3
CHLOROFORM	6,000,000	C	3
MESITYL OXIDE - DEHYDROGENATION	6,000,000	D	3
VINYL CHLORIDE - ACETYLENE	5,000,000	C	3
CARBON BLACK - THERMAL	3,000,000	C	3
1,1,1-TRICHLOROETHANE - VINYLIDENE CHLORIDE HYDROCHLORINATN	3,000,000	C	3
ACROLEIN	3,000,000	C	3
TOLUENE - COAL	2,000,000	C	2
DODECENE - NON-LINEAR	2,000,000	C	3
ETHYLENE GLYCOL - ETHYLENE OXIDE	900,000	B	2
ETHYLENE OXIDE	600,000	D	2
ISOAMYLENE	600,000	D	3
XYLENES - MIXED - COAL	500,000	C	3
PHTHALIC ANHYDRIDE - O-XYLENE	500,000	B	3
NEOPENTANOIC ACID	400,000	C	3
CYCLOOCTADIENE - BUTADIENE	300,000	D	3
N-BUTYL ALCOHOL - ZIEGLER PROCESS	300,000	C	3
METHYL ETHYL KETONE - FROM S-BUTYL ALCOHOL	300,000	B	3
P-XYLENE	200,000	B	2
ISOPHORONE	100,000	D	3
METHYL CHLORIDE - METHANOL	100,000	B	3
DIETHYLENE GLYCOL	100,000	B	3
ISOPRENE - PETROLEUM FRACTIONS	100,000	D	3
SULFOLANE	90,000	D	3
1,1,1-TRICHLOROETHANE - ETHANE CHLORINATION	50,000	C	3
BENZENE - OTHER	[illegible]0,000	C	3
ALKYLNAPHTHALENE	30,000	C	3
POLYETHYLENE GLYCOLS	10,000	C	3
CUMENE		B	2

[a] Impact factors have been multiplied by a scaling factor of 10^6 to avoid dealing with numbers much less than 1.0.

[b] Uncertainty level (see page 17).

[c] Type of calculation (degree of data aggregation):

1 = aggregated according to population;
2 = aggregated on a state basis;
3 = detailed plant data.

TABLE 2. PRIORITIZATION OF PESTICIDE SOURCES OF WATER POLLUTION

SOURCE TYPE	IMPACT FACTOR[a]	CL[b]	CALC[c]
PHORATE	600,000,000	D	3
ENDOSULFAN	300,000,000	D	3
DIMETHOATE	300,000,000	D	3
CHLORAMBEN	200,000,000	D	3
MALATHION	100,000,000	D	3
AZODRIN	90,000,000	D	3
DIAZINON	50,000,000	B	3
PARATHION	40,000,000	B	3
CHLOROBENZILATE	30,000,000	C	3
LINDANE	30,000,000	D	3
DICAMBA	30,000,000	D	3
PROPACHLOR	20,000,000	C	3
BUTACHLOR	20,000,000	D	3
ALACHLOR	20,000,000	C	3
MANEB	20,000,000	B	3
PCP	10,000,000	B	3
DISULFOTON	10,000,000	B	3
CDAA	10,000,000	C	3
BENSULIDE	10,000,000	D	3
CHLORDANE	10,000,000	C	3
ATRAZINE	10,000,000	D	3
CARBOPHENOTHION	9,000,000	D	3
AMITROLE	8,000,000	D	3
FONOPHOS	8,000,000	D	3
METHOXYCHLOR	7,000,000	D	3
SODIUM CHLORATE	7,000,000	B	3
DICOFOL	6,000,000	D	3
SILVEX	6,000,000	D	3
SIMAZINE	5,000,000	C	3
COPPER SULFATE	5,000,000	B	3
CHLORONEB	4,000,000	D	3
METHYL PARATHION	4,000,000	B	3
FENSULFOTHION	4,000,000	B	3
PROPAZINE	3,000,000	D	3
ETHION	3,000,000	D	3
2,4-D	3,000,000	C	3
DEF	3,000,000	D	3
PROMETONE	3,000,000	D	3
THIONAZIN	2,000,000	D	3
ABATE	2,000,000	D	3
AZINPHOS - METHYL	2,000,000	C	3
FENAC	1,000,000	D	3
DEET	1,000,000	D	3
2,4,5-TRICHLOROPHENOL	1,000,000	D	3
MOCAP	1,000,000	D	3
HEPTACHLOR	1,000,000	C	3
CAPTAN	900,000	D	3
NITRALIN	800,000	D	3
METHOMYL	800,000	D	3
PCNB	800,000	B	3
FERBAM	600,000	D	3
METRIBUZIN	600,000	B	3
2,4,5-T	500,000	C	3
BENOMYL	500,000	D	3
FENTHION	400,000	B	3
CARBARYL	300,000	C	3
2,4,5-T SALTS	300,000	C	3
RONNEL	300,000	C	3
DINOSEB	200,000	B	3
METALKAMATE	200,000	D	3
ALDICARB	100,000	D	3
DEMETON	100,000	C	3
DIOXATHION	100,000	D	3
LINURON	100,000	C	3
VERNOLATE	80,000	D	3
FENITROTHION	80,000	D	3
CARBOFURAN	70,000	D	3
TEPP	60,000	D	3
ENDRIN	60,000	B	3
CHLORPYRIFOS	50,000	C	3
EPTC	50,000	D	3
TERRAZOLE	50,000	C	3
DICHLOFENTHION	50,000	D	3
COUMAPHOS	50,000	C	3
TRIFLURALIN	30,000	D	3
BROMACIL	20,000	C	3
POLYRAM	20,000	D	3
MOLINATE	20,000	D	3
LEAD ARSENATE	20,000	D	3
DIURON	20,000	C	3
CYCLOATE	10,000	D	3
PEBULATE	10,000	D	3
TOXAPHENE	10,000	C	3
CHLORPROPHAM	10,000	D	3
TRIALLATE	10,000	D	3
PROPANIL	9,000	D	3
NABAM	9,000	D	3
METHYL DEMETON	7,000	C	3
ZINEB	5,000	B	3
CDEC	5,000	D	3
DIALLATE	5,000	D	3
CRUFOMATE	4,000	D	3
NALED	3,000	C	3

(continued)

TABLE 2 (continued)

SOURCE TYPE	IMPACT FACTOR[a]	CL[b]	CALC[c]
TERBACIL	3,000	D	3
DICROTOPHOS	2,000	D	3
TEBUTHIURON	2,000	C	3
DALAPON	2,000	C	3
BENEFIN	1,000	C	3
MONURON	1,000	D	3
PHOSPHAMIDON	1,000	D	3
FLUOMETRON	900	D	3
NEBURON	600	D	3
MEVINPHOS	500	C	3
DICHLORVOS	100	D	3
ASPON	90	D	3
BUTYLATE	80	D	3
PYRETHRINS	70	D	3
CACODYLIC ACID	60	D	3

[a] Impact factors have been multiplied by a scaling factor of 10^6 to avoid dealing with numbers much less than 1.0.

[b] Uncertainty level (see page 17).

[c] Type of calculation (degree of data aggregation):

1 = aggregated according to population;
2 = aggregated on a state basis;
3 = detailed plant data.

TABLE 3. PRIORITIZATION OF FERTILIZER SOURCES OF WATER POLLUTION

SOURCE TYPE	IMPACT FACTOR[a]	CL[b]	CALC[c]
AMMONIUM NITRATE	80,000,000	C	2
AMMONIA	60,000,000	C	2
UREA	50,000,000	C	2
NITRIC ACID	2,000,000	C	2
FERTILIZER MIXING - AMMONIATION - GRANULATION PLANTS		C	2
PHOSPHORIC ACID - WET PROCESS		C	2
FERTILIZER MIXING - LIQUID MIX PLANTS		C	2
SUPERPHOSPHATE - NORMAL		C	2
SULFURIC ACID		C	2
PHOSPHATE ROCK - DRYING, GRINDING, CALCINING		C	2
AMMONIUM PHOSPHATES		C	2
FERTILIZER MIXING - BULK BLENDING PLANTS		C	2
AMMONIUM SULFATE		C	3
TRIPLE SUPERPHOSPHATES		C	3
POTASH - POTASSIUM SALTS		C	3
MANGANESE SULFATE		C	3

[a] Impact factors have been multiplied by a scaling factor of 10^6 to avoid dealing with numbers much less than 1.0.

[b] Uncertainty level (see page 17).

[c] Type of calculation (degree of data aggregation):

1 = aggregated according to population;
2 = aggregated on a state basis;
3 = detailed plant data.

TABLE 4. PRIORITIZATION OF TEXTILE SOURCES OF WATER POLLUTION

SOURCE TYPE	IMPACT FACTOR[a]	CL[b]	CALC[c]
KNITTING MILLS	1,000,000,000	D	2
MAN-MADE FIBER AND SILK FINISHING MILLS	1,000,000,000	D	2
THROWING AND WINDING MILLS	1,000,000,000	D	2
COTTON WEAVING MILLS	800,000,000	D	2
FELT GOODS EXCEPT WOVEN FELTS AND HATS	700,000,000	D	2
COTTON FINISHING MILLS	700,000,000	D	2
MAN-MADE FIBER AND SILK WEAVING MILLS	600,000,000	D	2
WOOL YARN MILLS	300,000,000	D	2
NONWOVEN FABRICS	200,000,000	D	2
FINISHING MILLS - N E C	70,000,000	D	2
FLOOR COVERING MILLS	30,000,000	D	2
YARN MILLS EXCEPT WOOL	30,000,000	D	2
WOOL WEAVING AND FINISHING MILLS	30,000,000	D	2
COATED FABRICS NOT RUBBERIZED	10,000,000	D	2
NARROW FABRIC MILLS	8,000,000	D	2
TIRE CORD AND FABRIC	3,000,000	D	2
PROCESSED TEXTILE WASTE	2,000,000	D	2
PADDINGS AND UPHOLSTERY FILLING	2,000,000	D	2
CORDAGE AND TWINE	1,000,000	D	2
TEXTILE GOODS - N E C	900,000	D	2
THREAD MILLS	200,000	D	2
LACE GOODS	200,000	D	2

[a] Impact factors have been multiplied by a scaling factor of 10^6 to avoid dealing with numbers much less than 1.0.

[b] Uncertainty level (see page 17).

[c] Type of calculation (degree of data aggregation):

1 = aggregated according to population;
2 = aggregated on a state basis;
3 = detailed plant data.

SECTION 3

WATER PRIORITIZATION MODEL

THE MATHEMATICAL MODEL

A mathematical model was developed to provide a ranking of industrial wastewater sources. Although this approach does not eliminate subjective judgment, it does make the prioritization process visible and open to scrutiny. Many different mathematical models can be conceived in this instance because the system to be studied is complex and not fully understood. Pertinent factors that deserve consideration are: the number of industrial source types, the flow rate of each discharge stream, discharge stream composition (chemical and physical characteristics), volume and flow rate of the receiving body, water quality of the receiving body, and the hazardous nature of the discharge stream. In an effluent stream containing many materials, each species may have a different environmental impact, and there may be synergestic interactions.

For prioritization purposes it was decided to adopt a simplified approach because the model is intended only to rank sources in a relative way as a basis for further study. Four simple models were considered, based on the degree of mixing with the receiving stream. In the first case, the source severity (S) was defined for each discharge by:

$$S_A = \frac{cd}{F} \tag{1}$$

where S_A = severity due to a pollutant in a discharge stream before dilution
cd = concentration of pollutant in effluent, g/m^3
F = hazard factor equal to a potentially hazardous concentration, g/m^3 (see Equations 11 to 17 later in text)

Equation 1 describes what may be termed the end-of-pipe severity for the discharge stream. Once an effluent enters a receiving body it is diluted by the receiving body water so that the severity decreases. The severity within a mixing zone, MZ, is defined as follows:

$$S_B = \left(\frac{vd}{vd + A \cdot vr}\right)\left(\frac{cd}{F}\right) \qquad (2)$$

where S_B = severity due to a pollutant in a mixing zone
vd = effluent discharge rate, m^3/s
vr = river flow rate, m^3/s
A = fraction of river flow in mixing zone; i.e., 1/3, 1/4

The severity after the mixing zone, S_C, is given by:

$$S_C = \left(\frac{vd}{vd + vr}\right)\left(\frac{cd}{F}\right) \qquad (3)$$

where S_C = severity due to a pollutant after a mixing zone

These relationships are shown in Figure 1.

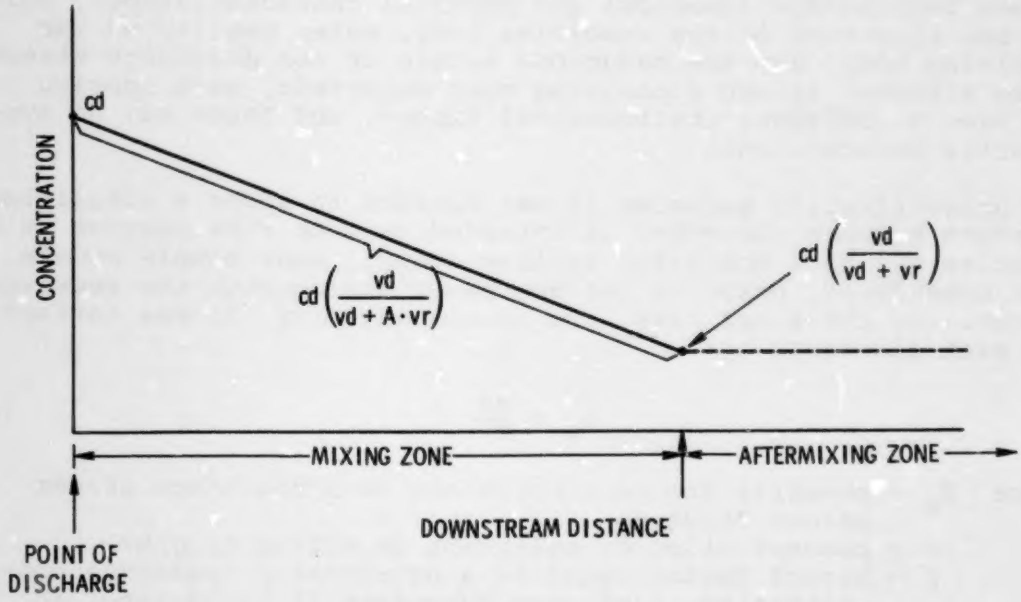

Figure 1. Change of concentration with distance.

If vr is much greater than vd, then

$$S_C = \left(\frac{vd}{vr}\right)\left(\frac{cd}{F}\right) \qquad (4)$$

Equation 4 defines the severity used as a starting basis for the water prioritization model. It is important to note that this severity is not an aggregate parameter, but instead refers to one pollutant within one discharge stream. A complete discussion of the severity model is presented in Appendix A.

Oxygen Demand Severity

For pollutant species that deplete the dissolved oxygen content of receiving streams, a different approach was required. The aftermixing zone, AMZ, severity for oxygen demand was defined in a manner analogous to that for other pollutants. First, an excess oxygen concentration, F_o, is defined by

$$F_o = \begin{cases} cs - DO \text{ when } cs - DO \geq 1.0 \\ 1.0 \text{ when } cs - DO < 1.0 \end{cases} \qquad (5)$$

where cs = saturated dissolved oxygen concentration, g/m^3
DO = dissolved oxygen freshwater quality criterion, g/m^3

The AMZ oxygen deficit severity is

$$So = \left(\frac{vd}{vr}\right)\left(\frac{TOD}{F_o}\right) \qquad (6)$$

where So = oxygen deficit severity
TOD = total oxygen demand, g/m^3

Oxygen demand can also be measured as COD (chemical oxygen demand) or BOD (biological oxygen demand). Appendic B discusses the relationship between TOD, COD, and BOD, and presents the methodology for determining So when COD, BOD, and/or TOC (total organic carbon) data are available for an effluent stream.

Solid Leachate Contribution

Whenever solid wastes from an industrial source are exposed to rainfall, soluble materials leach out and can potentially enter surface waterways. This leachate contribution to the environmental impact is included in the severity model. A description of the solid leachate contribution to the water severity model is given in Appendix A.

Water Impact Factor

Once severities have been defined for each pollutant, it is necessary to aggregate them on a plant and industry basis. In this way the environmental impact of many different industries can all be compared on a relative basis.

A plant source severity was computed as the square root of the sum of individual squares of all pollutants' source severities as follows:

$$S_j = \left(So_j^2 + S_{1j}^2 + S_{2j}^2 + S_{3j}^2 + \ldots + S_{Nj}^2\right)^{1/2} \qquad (7)$$

where S_j = total water severity at the jth plant (including oxygen demand severity)
So_j = oxygen deficit severity at the jth plant
S_{ij} = water severity for the ith pollutant at the jth plant

The overall water impact factor, Iw_x, is the summation of the plant severities over the Z plants in source type x.

$$Iw_x = \sum_{j=1}^{Z} S_j \qquad (8)$$

or

$$Iw_x = \sum_{j=1}^{Z} \left[\left(So_j\right)^2 + \sum_{i=1}^{N} \left(S_{ij}\right)^2\right]^{1/2} \qquad (9)$$

In order to avoid working with numbers much less than one, the impact factor was multiplied by a scaling factor of 10^6. This introduces no problems because the impact factor is only used to relatively rank source types.

ASSUMPTIONS, LIMITATIONS, AND CAVEATS

Ideally, source type impact factors should be computed with a high degree of precision from discharge rate time histories and receiving body flow rates for all plants. Such data are scarce, however, and aggregating available data for a number of the terms that were derived was necessary. This aggregating process is described in Appendix C.

This prioritization model assumes that all sources discharge into a moving receiving stream. This is obviously not the case. A number of Texas and California industries discharge directly into estuaries or into the ocean; plants on the eastern seaboard may discharge directly into the ocean; industries in the Great Lakes region discharge directly into the lakes. Other plants dispose of their effluents by deep well injection. Time and cost constraints on this project did not allow for individual plant location identification in many cases.

A large number of plants may discharge directly into municipal treatment facilities, with subsequent discharge into a receiving stream. For the purposes of this initial ranking, these plants were assumed to discharge directly into the receiving stream. An attempt was made to make an overall potential industry burden determination and not necessarily a detailed plant-by-plant evaluation. A detailed assessment of the actual water pollution problem will be performed on an industry-by-industry basis using the initial ranking as one of several guides to selecting industries for in-depth assessment.

Intake water quality was considered initially, but was later deleted from the model. Since water pollution regulations are written for discharged mass of various species regardless of intake water quality, the model was formulated in an analogous fashion.

The solid residue portion of the prioritization model is simplistic; but from a worst case point of view, it should be adequate for a relative ranking. A number of factors were considered but not included; biodegradability and transformation rates, ecological magnification in food chains, and ambient species concentrations were the major omissions. Time and cost constraints or lack of information were the major reasons for their exclusion.

The following caveats pertain to this model:

- This prioritization model was designed to be used as just one tool in aiding the IERL decision makers in their planning process. The ranking of industries should not be considered rigid; rather, industries in the top 25% are likely to impose a greater environmental burden than industries in the bottom 25%.
- Usage of the models described in Appendix A for purposes other than relative ranking of water severity may not be appropriate.
- The absolute value of any impact factor taken out of context has no significance.
- Synergistic effects among multiple pollutants in a discharge were not considered.
- Reaeration of streams was not considered.

MODEL APPLICATIONS

To calculate impact factors for a given source type the basic input parameters are vd, cd, vr, and F. These must be known on a plant-by-plant basis for each pollutant species. For prioritization purposes it was impossible to identify the receiving body (and thus vr) for every plant, and an average river flow rate was therefore determined for each state. Appendix C presents a tabulation of the average river flow rates, which were compiled from state water resource reports. Average rainfall rates are also given for use in calculating leaching rates from solid wastes. Plant sites were then located by state and assigned the appropriate vr value.

Effluent Data

Effluent data needed to calculate water severities are the volumetric flow rate of the effluent (vd) and the pollutant concentration in the effluent (cd). In many cases data of this type were not available for a source type, and an alternate procedure had to be employed. The product vd•cd is a mass flow rate (grams per second), and data were sometimes presented directly in this manner. At other times effluent factors (gram of pollutant per kilogram of product) were given, and these were combined with production data (kilogram of product produced per second) to yield mass flow rates. In a few instances cd was known together with the wastewater loading (cubim meter of effluent per kilogram of product), and the product of these factors and the production rate gave the required mass flow rate.

In order to minimize manual computations during prioritization, input data sheets were prepared for each source type (see Appendix D for sample data sheets). Data were recorded in the format in which they were available and in English or metric units, according to common usage. A computer program converted the data into a uniform base of annual water effluent mass loading (X, g/yr), determined the source severity for each pollutant at each plant, and calculated the aggregate impact factor. The relevant conversion equations employed were:

$$X = \begin{cases} E_R k_1 \\ (PC) E_F k_2 \\ (L)(C)(PC) k_3 \end{cases} \tag{10}$$

where X = annual water effluent mass loading, g/yr
E_R = effluent rate, tons/yr
PC = plant capacity, tons/yr
E_F = effluent factor, lb/ton
L = wastewater loading, gal/ton
C = concentration of species in discharge, mg/liter
k_1 = conversion factor, g/ton
k_2 = conversion factor, g/lb
k_3 = conversion factor, (g/mg)(liter/gal)

It should be noted that plant capacities were normally used in place of production rates because capacity data were much more readily available. Pollutant concentrations are generally reported in milligrams per liter, C, but this is numerically equal to the concentration in grams per cubic meter, cd. The computer program converted X from grams per year into grams per second to make it compatible with the river flow rates which are reported in cubic meters per second.

For some source types, production or capacity data were only available on a state-by-state basis. In these cases it was possible to calculate severities for every state because the denominator in the severity equation (vr•F) is the same for all plants within a state. It is assumed that a common effluent factor applies to all plant sites.

Hazard Factors

Hazard factors were developed to correspond to a concentration in river water that was potentially hazardous to aquatic life or human health. They were selected first from water quality criteria if they were available. The development of hazard factors for the prioritization model and a listing of hazard factors for various organic and inorganic chemical substances is shown in Appendix E. In the absence of defined criteria, hazard factors were calculated by one of the following equations:

$$F_1 = 0.05 \times LC_{50} \text{ (96-hr) (Ref. 1)} \quad (11)$$

$$F_2 = 0.05 \times LC_{50} \text{ (48-hr or 24-hr)} \quad (12)$$

$$F_3 = 0.05 \times (LC_{Lo}, TC_{Lo}, IC_{50}) \quad (13)$$

$$F_4 = 2.25 \times 10^{-3} \times LD_{50} \text{ (oral/rat) (Ref. 2)} \quad (14)$$

$$F_5 = 2.25 \times 10^{-3} \times LD_{50} \text{ (other than oral/rat)} \quad (15)$$

$$F_6 = 2.25 \times 10^{-3} \times (LD_{Lo}, TD_{Lo}) \quad (16)$$

$$F_7 = 7.76 \times 10^{-3} \times TLV^{®} \text{ (Ref. 2, 3)} \quad (17)$$

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(1) Walden, C. C., and T. E. Howard. Toxicity: Research and Regulation. In: Proceedings of 1976 Technical Association of the Pulp and Paper Industry Environmental Conference, Atlanta, Georgia, April 26-28, 1976. pp. 93-99.

(2) Handy, R. W., and M. Samfield. Estimate of Permissible Concentrations of Pollutants for Continuous Exposure; Part II: Permissible Water Concentrations. Contract 68-02-1325, Task 34, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, September 1975. 36 pp.

(3) TLVs® Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1975. American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio, 1975. 97 pp.

where $F_1 \ldots F_7$ = hazard factors
LC_{50} = lethal concentration of a substance that will kill 50% of a group of experimental insects or animals
LC_{Lo} = lowest published lethal concentration
TC_{Lo} = lowest published toxic concentration
IC_{50} = concentration of a substance that will immobilize 50% of a group of experimental insects or animals
LD_{50} = calculated dose of a chemical substance which is expected to cause death of 50% of an entire population of an experimental animal species
LD_{Lo} = lowest published lethal dose
TD_{Lo} = lowest published toxic dose
TLV = threshold limit value

The rank of the above equations was based on evidence from scientific studies on the relative availability of specific toxicity indicators.

The method for evaluating hazard factors (using Equation 11) originates from studies directed toward determining the effluent concentration below which no stress is exerted on aquatic organisms. Considerable evidence now exists that this concentration is about 0.05 to 0.10 of the 96-hr LC_{50} value (1).

The ideal data base would consist of information on a large percentage of aquatic species and would show the community response to a range of concentrations during a long time period. Because this information is not available, test organisms are used to represent expected results for other associated organisms. Certain test animals have been selected for intensive research because of their importance to man, their availability, and their physiological responses to the laboratory environment. In this context, *Daphnia* or other associated organisms indicate the general levels of toxicity to be expected among untested species. If data for *Daphnia* are not available, values for fatheat minnows, bluegill, and other types of fish, such as trout, are used.

In the absence of 96-hr LC_{50} data, 48-hr LC_{50} values may be utilized bacuase there is often little appreciable difference between a 96-hr value and a 48-hr value. In some cases data are presented in terms of 24-hr LC_{50}, LC_{Lo}, TC_{Lo} (toxic concentration low), or IC (immobilization concentration). These values were multiplied by 0.05 to arrive at a hazard factor in analogy to Equation 12.

When LC_{50} data are lacking, methods depend on the relative availability of specific toxicity indicators. The most common indicator of toxicity is the LD_{50} (oral/rat) value. The authors of Equation 14 postulate that the result represents the maximum concentration which has no effect on human health when 0.002 m^3 (2 liters) are consumed daily (2). In the absence of LD_{50} (oral/rat) data, values for LD_{50} (other species), LD_{Lo}, or TD_{Lo} were employed, using the same coefficient as in Equation 14.

Several cases arise where the only indication of toxicity is a TLV. As proposed, Equation 17 assumes that the total amount of contaminant in 10 m^3 (average adult respiratory tidal volume in 24 hr) of air may be contained in 0.002 m^3 (2 liters) of drinking water.

Most toxicity information is not intended for use in assessing industrial effluent. For instance, practically no information exists for the toxic properties of complex effluents. This methodology attempts to establish a workable, consistent way to formulate potential hazard factors using available data.

Water quality criteria provided approximately 10% of the hazard factors. The remaining 90% were calculated using Equations 11 through 17. A detailed listing of hazard factors is presented in Appendix E.

Example

In order to further clarify the working of the prioritization model an impact factor is calculated for a hypothetical source type. The source type consists of three plants located in two states, Ohio and New York. Each plant has one discharge stream containing three pollutants. Relevant input data are given in Table 5. Severities are calculated as follows:

$$S(\text{Plant A}) = (S^2_{\text{phenol}} + S^2_{\text{chromium}} + S^2_{\text{lead}})^{1/2}$$

$$S_{\text{phenol}}\ (\text{Plant A}) = \frac{(0.01\ \text{g/kg})(200 \times 10^3\ \text{metric tons/yr})}{(416.26\ \text{m/s})(0.001\ \text{g/m}^3)}$$

$$\frac{(10^3\ \text{kg/metric ton})\ 10^6}{(3.15 \times 10^7\ \text{s/yr})}$$

where the factor 10^6 in the numerator is a scaling factor. Then,

$$S_{\text{phenol}}\ (\text{Plant A}) = 152{,}000$$

Severities for other pollutants are computed in a similar way and are all shown in Table 5. The severity for Plant A is then

TABLE 5. EXAMPLE OF INPUT DATA AND RESULTS FOR CALCULATION OF WATER SEVERITY

Plant Data

Plant	Location	vr, m^3/s	Plant capacity, 10^3 metric tons/yr
A	Ohio	416.26	200
B	New York	526.70	100
C	New York	526.70	300

Effluent Data

Pollutant	Hazard factor, g/m^3	Effluent factor, g/kg
Phenol	0.001	0.01
Chromium	0.05	0.02
Lead	0.05	0.001

Source Severity Values[a]

Plant	Phenol	Chromium	Lead	Total plant
A	152,500	61,000	3,000	164,000
B	60,300	24,100	1,200	65,000
C	180,800	72,300	3,600	195,000
Total	NA[b]	NA	NA	Iw_x = 424,000

[a] Severities are multiplied by a scaling factor of 10^6.

[b] Not applicable.

$$S\ (\text{Plant A}) = (23{,}256 \times 10^6 + 3{,}721 \times 10^6 + 9 \times 10^6)^{1/2}$$

$$= 164{,}000$$

Severities for Plants B and C are calculated in the same way and are shown in the table. The overall impact factor is:

$$Iw_x = 164{,}000 + 65{,}000 + 195{,}000$$

$$= 424{,}000$$

Appendix C presents a detailed calculation for one of the organic source types actually prioritized, ethylene dichloride-ethylene chlorination.

Data Validity

A level of uncertainty is associated with each impact factor. While the level cannot be quantified, it can be assumed to vary as a function of the quality of available information on a specific source type. Using this rationale, priority index uncertainty levels were defined as follows (4, 5):

Level	Meaning
A	Adequate data of reasonable accuracy
B	Partially adequate data of indeterminate accuracy
C	Totally estimated data of indeterminate accuracy
D	Missing data on known emissions of toxic substances

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(4) Eimutis, E. C., C. M. Moscowitz, J. L. Delaney, R. P. Quill, and D. L. Zanders. Air, Water, and Solid Residue Prioritization Models for Conventional Combustion Sources. EPA-600/2-76-176 (PB 257 103), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, July 1976. 57 pp.

(5) Eimutis, E. C. Source Assessment: Prioritization of Stationary Air Pollution Sources--Model Discription. EPA-600/2-76-032a (PB 253 479), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, February 1976. 83 pp.

SECTION 4

SOURCE PRIORITIZATIONS

PETROCHEMICAL SOURCE TYPES

Source Definition

Refinery-associated chemicals and chemicals currently being studied by Monsanto Research Corporation comprise the list of petrochemical source types to be prioritized. Only those petrochemical source types being studied for IERL-RTP were prioritized; sources being studied for IERL-Cincinnati were not included.

A chemical facility is considered to be refinery associated if the company or parent company has a refinery at the same site. Natural gas liquid production plants were considered equivalent to refineries. Examples of refinery-associated chemicals are benzene, toluene, and propylene. Acetone from cumene and acetophenone from cumene source types are accounted for by the phenol from cumene source type. Those chemicals are produced during the production of phenol from cumene. Similarly, acetonitrile from acrylonitrile and hydrogen cyanide from acrylonitrile source types are accounted for by the acrylonitrile source type.

Data Acquisition and Input Format

Water discharges were taken as total effluents from each production site. Characterization of water discharged identified 18 pollutants and pollution indicators plus specific organic species, where identifiable. The 18 parameters are listed in Table 6. Information required for each species was a hazard factor and an effluent factor. Raw wastewater loading and an uncertainty level were also included.

The 18 parameters shown in Table 6 do not represent a comprehensive description of the wastewater; rather, they are the parameters for which quantitative information was available. As an example, Table 7 lists materials that have been identified in acrylonitrile plant wastewater, both quantitatively and

TABLE 6. LIST OF POLLUTANTS AND INDICATORS OF POLLUTION

Pollutant or indicator	Abbreviation
Biochemical oxygen demand	BOD
Chemical oxygen demand	COD
Total organic carbon	TOC
Phenols	Phenols
Ammonia nitrogen	NH_3-N
Total Kjeldahl nitrogen	TKN
Cyanide--distillation	CN
Sulfate	Sulfate
Oil (freon extractables)	Oil
Total phosphorus	T-P
Zinc	Zn
Copper	Cu
Iron	Fe
Chromium--total	Cr-total
Cadmium	Cd
Total suspended solids	TSS
Total dissolved solids	TDS
Chlorine--residual	Cl_2

TABLE 7. ACRYLONITRILE PLANT WASTEWATER (6)[a]

Materials which have been quantitatively identified include

Ammonia nitrogen (as N_2)
Biochemical oxygen demand
Cadmium
Chemical oxygen demand
Chloride
Chromium
Copper
Iron
Nitrile nitrogen (as N_2)
Oil and grease
Phenol
Phosphate
Raw wastewater
Sulfate
Total dissolved solids
Total nitrogen (as N_2)
Total organic carbon
Total solids
Total suspended solids
Zinc

Compounds which have been qualitatively identified include

Acetaldehyde
Acetaldehyde cyanohydrin
Acetic acid
Acetone
Acetone cyanohydrin
Acetonitrile
Acrolein
Acrolein cyanohydrin
Acrylamide
Acrylic acid
Acrylonitrile
Allyl cyanide
Ammonium acetate
Ammonium acrylate
Ammonium formate
Ammonium methacrylate
Benzene
Benzonitrile
cis-Crotonitrile
trans-Crotonitrile
Cyanopyrazine
Fumaronitrile
Furonitrile
Hydrogen cyanide
Lutidine compounds
Maleonitrile
Malononitrile
Methacrylonitrile
Methyl pyrazine
Nicotinonitrile
Organic polymers
Propionitrile
Pyrazine
Pyrazole
Succinonitrile
Ticoline
Toluene

[a] Personal communication with A. W. Busch, Regional Administrator, Region IV, U.S. Environmental Protection Agency, Atlanta, Georgia, February 1974.

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(6) Train, R. E. Development Document for Interim Final Effluent Limitations Guidelines and New Source Performance Standards for the Significant Organic Products Segment of the Organic Chemicals Manufacturing Point Source Category. EPA-440/1-75/045, U.S. Environmental Protection Agency, Washington, D.C., November 1975. 391 pp.

qualitatively (Reference 6 and personal communication with A. W. Busch, Regional Administrator, Region IV, U.S. Environmental Protection Agency, Atlanta, Georgia, February 1974).

Hazard factors were calculated using information and procedures discussed earlier. Effluent factor information was compiled from several sources of information (6, 7). Specific effluent factors were available for some source types, such as hexamethylenediamine and terephthalic acid. Effluent factors for the remaining source types were estimated using the average water discharge effluent factors listed in Table 8 (6-8) by category. The categories are defined on page 21.

TABLE 8. AVERAGE WATER DISCHARGE CHARACTERIZATION BY CATEGORY TYPE (6-8)
(kg/metric ton)

Pollutant	Category A	Category B	Category C	Category D_1	Category D_2 (dyes)
BOD_5	0.0223	9.959	38.08	65.56	715.6
COD	0.4429	31.93	117.1	214.7	3,813.4
TOC	0.1511	18.37	54.55	59.55	970.9
Phenol	0.000334	0.0173	0.856	0.175	10.6
NH_3-N	0.00414	1.59	3.14	26.8	7.76
TKN	0.0139	2.51	20.42	62.55	18.17
CN	0.00004	0.093	0.074	0.00196	0.196
Sulfate	0.4559	13.86	28.12	1,406.2	179.16
Oil	0.1316	1.216	2.983	545.48	40.49
T-P	0.000192	0.076	0.0151	0.385	3.93
Zn	0.002	0.017	0.064	0.108	0.251
Cu	0.00123	0.014	0.227	0.024	0.971
Fe	0.00118	0.0447	0.0956	0.253	3.558
Cr-total	0.00075	0.0029	0.0047	0.0126	0.70
Cd	0.0000267	0.000028	0.00234	0.1621	0.029
TSS	0.0286	5.855	21.269	7,606.75	11.51
TDS	4.624	97.59	910.8	1,301.1	12,260.9
Cl_2	2.847	64.06	186.7	96.1	269.2
Raw wastewater load, 10^{-3} m^3/metric ton[a]	448.09	5,774.3	92,623.0	62,583	453,101

[a] 1 metric ton equals 10^6 grams; conversion factors and metric system prefixes are presented at the end of this report.

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(7) Train, R. E. Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Major Organic Products Segment of the Organic Chemicals Manufacturing Point Source Category. EPA-440/1-73/009, U.S. Environmental Protection Agency, Washington, D.C., December 1973. 369 pp.

(8) Hedley, W. H., S. M. Mehta, C. M. Moscowitz, R. B. Reznik, G. A. Richardson, and D. L. Zanders. Potential Pollutants from Petrochemical Processes. Technomic Publishing Co., Westport, Connecticut, 1975. 362 pp.

Category A: Nonaqueous Processes--
Minimal contact occurs between water and reactants or products within the process. Water is not required as a reactant or diluent and is not formed as a reaction product. The only water used stems from periodic washes of working fluids or catalyst hydration.

Category B: Processes with Process Water Contact versus Steam Diluent or Absorbent--
Process water is used in the form of dilution steam or direct contact quench or as an absorbent for reactor effluent gases. Reactions are all vapor phase and are carried out over solid catalysts. Most processes have an absorber coupled with steam stripping of chemicals for purification and recycle. Steam is also used for decoking of catalyst.

Category C: Continuous Liquid-Phase Reaction Systems--
These are liquid-phase reactions where the catalyst is in an aqueous medium such as dissolved or emulsified mineral salt or acid-caustic solution. Continuous regeneration of catalyst system requires extensive water usage. Substantial removal of spent inorganic salt byproducts may also be required. Working aqueous catalyst solution is normally corrosive. Additional water may be required in the final purification or neutralization of products.

Category D_1: Batch and Semicontinuous Processes--
Processes are carried out in reaction kettles equipped with agitators, scrapers, reflux condensers, etc., depending on the nature of the operations. Many reactions are liquid phase with aqueous catalyst systems. Reactants and products are transferred from one piece of equipment to another by gravity flow, pumping, or pressurization with air or inert gas. Much of the material handling is manual with limited use of automatic process control. Filter presses and centrifuges are commonly used to separate solid products from liquid. When drying is required, air or vacuum ovens are used. Cleaning of noncontinuous production equipment constitutes a major source of wastewater. Waste loads from product separation and purification will be at least 10 to 100 times those from continuous processes.

Category D_2: Batch and Semicontinuous Processes, Dyes--
These processes are like those described in Category D_1 (7). Effluent factors for specific organic species were also developed where possible (8). The effluent limitations of maximum discharge for any 1 day using the best practicable control technology currently available (BPCTCA) given in Table 9 were used (6). BPCTCA effluent limitations were selected because approximately 83%, or 3,337 out of 4,000, of the major industrial dischargers met the 1 July deadline for implementation of control technology

guidelines (9). Compliance is 85% in the chemical products industry and 83% for petroleum refining operations (9). Pollutants not having BPCTCA limitations were assumed to be uncontrolled.

TABLE 9. EFFLUENT LIMITATIONS, MAXIMUM FOR ANY ONE DAY, FOR THE BPCTCA (6)

Process	Effluent limitations, kg/metric ton BOD$_5$	TSS	Cyanide
Acrylonitrile	1.6	0.51	0.0045
Adiponitrile	1.1	1.1	0.0098
Benzene (fractional Distillation)	0.0039	0.0053	
s-Butyl alcohol	0.55	0.074	
Carbon tetrachloride (chlorination of methane)	0.22	0.33	
Chloroform (chlorination of methane)	0.22	0.33	
Cumene	—[a]	—[a]	—[a]
Hexamethylenediamine-adiponitrile	0.16	0.12	0.0010
Hexamethylenediamine-hexanediol	0.16	0.13	0.0011
Isobutylene	2.4	2.4	
Isopropanol	0.27	0.29	
Methyl chloride (chlorination of methane)	0.22	0.33	
Methylene chloride (chlorination)	0.22	0.33	
Methyl ethyl ketone	0.16	0.16	
Toluene (fractional distillation)	0.0039	0.0055	
Xylene (fractional distillation)	0.0039	0.0055	
p-Xylene	0.0035	0.0052	

Note.—Blanks indicate data not available.

[a] No discharge of process waste pollutants.

Producer, location, and capacity information was compiled for all sources. Examples of the input data sheets used are given in Appendix D.

Solid waste information was collected from varied sources (8, 10). The data sheet given in Appendix D was used to record it.

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(9) Chementator. Chemical Engineering, 84(14):63, 1977.

(10) Gruber, G. I. Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides, and Explosives Industries. EPA/530/SW-118c (PB 251 307), U.S. Environmental Protection Agency, Washington, D.C., April 1975. 377 pp.

Prioritization Listing

Table 10 alphabetically lists all petrochemical source types that were prioritized in this study.

TABLE 10. ALPHABETICAL LISTING OF PETROCHEMICAL SOURCE TYPES PRIORITIZED

Acetone--isopropanol
Acetonitrile
Acrolein
Acrylamide--from acrylonitrile
Acrylonitrile
Adipic acid
Adiponitrile
Alkylnaphthalene
Benzene--catalytic reformate
Benzene--coal derived
Benzene--other
Benzene--petrochemical feedstocks
Bisphenol-A
Butadiene--dehydrogenation of n-butane
Butadiene--ethylene byproduct
Butadiene--n-butene
n-Butyl alcohol
n-Butyl alcohol--Ziegler process
s-Butyl alcohol
t-Butyl alcohol
t-Butyl amine--isobutylene
n-Butyraldehyde
Carbon black--furnace
Carbon black--thermal
Carbon tetrachloride--carbon disulfide
Carbon tetrachloride--chlorination of propane
Carbon tetrachloride--methane
Chlorobenzene--chlorination of benzene
Chloroform
Cresylic acid
Cyclohexane
Cyclohexanol--from cyclohexane
Cyclohexanone
Cyclooctadiene--butadiene
Decyl alcohol
Diacetone alcohol--condensation
o-Dichlorobenzene
p-Dichlorobenzene
Diethylene glycol
Diisobutylene
Dimethyl terephthalate
Dodecene--nonlinear
Dodecyl alcohol--oxo process
Epichlorohydrin
Ethyl benzene--mixed xylenes
Ethyl benzene--benzene and mixed xylenes
Ethyl chloride--hydrochlorination of ethylene
Ethyl hexanol--oxo process
Ethylene
Ethylene dichloride--ethylene chlorination
Ethylene dichloride--oxychlorination
Ethylene glycol--ethylene oxide
Ethylene oxide
Glycerin--acrolein
Glycerin--allyl alcohol
Glycerin--epichlorohydrin

Heptane
Hexadecyl alcohol--oxo process
Hexamethylenediamine--adiponitrile
Hexamethylenediamine--ammonolysis of 1,6-hexanediol
Isoamylene
Isobutyl alcohol
Isobutylene--extraction of hydrocarbons
Isobutyraldehyde
Isodecanol--oxo process
Isooctyl alcohols
Isopentane
Isophorone
Isoprene--dehydrogeneation of isoamylenes
Isoprene--petroleum fractions
Isopropanol--propylene
Mesityl oxide--dehydrogenation
Methyl chloride--chlorination of methane
Methyl chloride--methanol
Methylene chloride--chlorination of methane
Methyl ethyl ketone--from s-butyl alcohol
Methyl isobutyl carbinol
Methyl isobutyl ketone
Naphthalene
Neopentanoic acid
Nonene
Nonylphenol
n-Pentane
Perchloroethylene--chlorination of propane
Phenol--cumene process
Phosgene
Phthalic anhydride--naphthalene
Phthalic anhydride--*o*-xylene
Polybutenes--butane
Polyethylene glycols
Propylene--from ethylene and refining--via pyrolysis
Propylene--from ethylene--via pyrolysis
Propylene oxide--chlorohydrin process
Propylene--refining--via pyrolysis
Styrene
Sulfolane
Terephthalic acid
Toluene--catalytic reforming
Toluene--coal
Toluene--petrochemical feedstocks
1,1,1-Trichloroethane--ethane chlorination
1,1,1-Trichloroethane--vinyl chloride chlorination
1,1,1-Trichloroethane--vinylidene chloride hydrochlorination
Trichloroethylene--chlorination of acetylene
Trichloroethylene--chlorination then dehydrochlorination of EDC
1,2,3-Trichloropropane
Triisobutylene
Vinyl chloride--acetylene
Vinyl chloride--ethylene
Xylenes--mixed--coal
Xylenes--mixed--petrochemical
o-Xylene

The petrochemical water prioritization listing was presented earlier in Table 1 and is repeated in Table 11 for reader convenience.

TABLE 11. PRIORITIZATION OF PETROCHEMICAL SOURCES OF WATER POLLUTION

SOURCE TYPE	IMPACT FACTOR[a]	CL[b]	CALC[c]
PROPYLENE OXIDE - CHLOROHYDRIN PROCESS	10,000,000,000	B	3
ADIPONITRILE	5,000,000,000	B	3
N-BUTYRALDEHYDE	5,000,000,000	C	3
PHENOL - CUMENE PROCESS	4,000,000,000	C	3
CHLOROBENZENE - CHLORINATION OF BENZENE	4,000,000,000	C	3
GLYCERIN - ALLYL ALCOHOL	4,000,000,000	C	3
GLYCERIN - EPICHLOROHYDRIN	4,000,000,000	C	3
P-DICHLOROBENZENE	3,000,000,000	C	3
ETHYLENE DICHLORIDE - ETHYLENE CHLORINATION	3,000,000,000	B	3
ETHYLENE DICHLORIDE - OXYCHLORINATION	3,000,000,000	C	3
CYCLOHEXANONE	3,000,000,000	C	3
ADIPIC ACID	3,000,000,000	C	3
VINYL CHLORIDE - ETHYLENE	3,000,000,000	C	3
CYCLOHEXANOL - FROM CYCLOHEXANE	2,000,000,000	C	3
BUTADIENE - N-BUTENE	2,000,000,000	C	3
ISOPROPANOL - PROPYLENE	2,000,000,000	C	3
PERCHLOROETHYLENE - CHLORINATION OF PROPANE	2,000,000,000	B	3
ISOOCTYL ALCOHOLS	2,000,000,000	C	3
ETHYL HEXANOL - OXO PROCESS	2,000,000,000	C	3
N-BUTYL ALCOHOL	1,000,000,000	C	3
ETHYLENE	1,000,000,000	C	2
EPICHLOROHYDRIN	1,000,000,000	C	3
CARBON TETRACHLORIDE - METHANE	1,000,000,000	C	3
ACETONE - FROM ISOPROPANOL	800,000,000	C	3
S-BUTYL ALCOHOL	800,000,000	B	3
ETHYL BENZENE - BENZENE AND MIXED XYLENES	700,000,000	B	3
BISPHENOL-A	700,000,000	B	3
CRESYLIC ACID	700,000,000	C	3
METHYL ISOBUTYL KETONE	700,000,000	C	3
O-DICHLOROBENZENE	500,000,000	C	3
METHYLENE CHLORIDE - CHLORINATION OF METHANE	500,000,000	C	3
POLYBUTENES - BUTANE	500,000,000	C	3
1,1,1-TRICHLOROETHANE - VINYL CHLORIDE CHLORINATION	400,000,000	C	3
PROPYLENE - REFINING - VIA PYROLYSIS	400,000,000	C	2
DIISOBUTYLENE	400,000,000	C	3
T-BUTYL ALCOHOL	300,000,000	C	3
BENZENE - CATALYTIC REFORMATE	300,000,000	C	2
DODECYL ALCOHOL - OXO PROCESS	300,000,000	C	3
TOLUENE - CATALYTIC REFORMING	300,000,000	C	2
NAPHTHALENE	300,000,000	C	2
CARBON TETRACHLORIDE - CHLORINATION OF PROPANE	200,000,000	C	3
HEXADECYL ALCOHOL - OXO PROCESS	200,000,000	C	3
ISOBUTYLENE - EXTRACTION OF HYDROCARBONS	200,000,000	C	3
ISOBUTYRALDEHYDE	200,000,000	C	3
CARBON TETRACHLORIDE - CARBON DISULFIDE	200,000,000	C	3
ACRYLONITRILE	200,000,000	B	3
ISODECANOL - OXOPROCESS	200,000,000	D	3
METHYL ISOBUTYL CARBINOL	200,000,000	C	3
TRICHLOROETHYLENE - CHLORINATN THEN DEHYDROCHLORINATN OF EDC	100,000,000	C	3
DECYL ALCOHOL	100,000,000	C	3
XYLENES - MIXED - PETROCHEMICAL	100,000,000	C	3
ISOPRENE - DEHYDROGENEATION OF ISOAMYLENES	100,000,000	C	3
NONENE	100,000,000	C	3
PROPYLENE - FROM ETHYLENE - VIA PYROLYSIS	100,000,000	C	2
NONYLPHENOL	90,000,000	C	3
PHTHALIC ANHYDRIDE - NAPTHALENE	90,000,000	C	3
PROPYLENE - FROM ETHYLENE AND REFINING - VIA PYROLYSIS	80,000,000	C	2
ISOPENTANE	80,000,000	D	3
CYCLOHEXANE	70,000,000	C	3
BUTADIENE - ETHYLENE BY-PRODUCT	70,000,000	B	3
ISOBUTYL ALCOHOL	60,000,000	C	3
O-XYLENE	50,000,000	C	3
BENZENE - PETROCHEMICAL FEEDSTOCKS	50,000,000	C	2

(continued)

TABLE 11 (continued)

SOURCE TYPE	IMPACT FACTOR[a]	CL[b]	CALC[c]
CARBON BLACK - FURNACE	40,000,000	C	2
N-PENTANE	40,000,000	D	3
ACRYLAMIDE - FROM ACRYLONITRILE	40,000,000	C	3
TOLUENE - PETROCHEMICAL FEEDSTOCKS	40,000,000	C	2
ETHYL CHLORIDE - HYDROCHLORINATION OF ETHYLENE	30,000,000	C	3
PHOSGENE	30,000,000	C	3
DIMETHYL TEREPHTHALATE	30,000,000	B	3
HEPTANE	30,000,000	C	3
TRIISOBUTYLENE	30,000,000	D	3
BUTADIENE - DEHYDROGENATION OF N-BUTANE	30,000,000	D	3
HEXAMETHYLENEDIAMINE - ADIPONITRILE	30,000,000	B	3
T-BUTYL AMINE - ISOBUTYLENE	20,000,000	C	3
DIACETONE ALCOHOL - CONDENSATION	20,000,000	C	3
1,2,3-TRICHLOROPROPANE	20,000,000	C	3
GLYCERIN - ACROLEIN	10,000,000	C	3
BENZENE - COAL DERIVED	9,000,000	C	2
ETHYL BENZENE - MIXED XYLENES	9,000,000	C	3
METHYL CHLORIDE - CHLORINATION OF METHANE	8,000,000	C	3
HEXAMETHYLENEDIAMINE - AMMONOLYSIS OF 1,6-HEXANEDIOL	7,000,000	C	3
TEREPHTHALIC ACID	6,000,000	B	3
STYRENE	6,000,000	B	3
TRICHLOROETHYLENE - CHLORINATION OF ACETYLENE	6,000,000	C	3
CHLOROFORM	6,000,000	C	3
MESITYL OXIDE - DEHYDROGENATION	6,000,000	D	3
VINYL CHLORIDE - ACETYLENE	5,000,000	C	3
CARBON BLACK - THERMAL	3,000,000	C	3
1,1,1-TRICHLOROETHANE - VINYLIDENE CHLORIDE HYDROCHLORINATN	3,000,000	C	3
ACROLEIN	3,000,000	C	3
TOLUENE - COAL	2,000,000	C	2
DODECENE - NON-LINEAR	2,000,000	C	3
ETHYLENE GLYCOL - ETHYLENE OXIDE	900,000	B	2
ETHYLENE OXIDE	600,000	D	2
ISOAMYLENE	600,000	D	3
XYLENES - MIXED - COAL	500,000	C	3
PHTHALIC ANHYDRIDE - O-XYLENE	500,000	B	3
NEOPENTANOIC ACID	400,000	C	3
CYCLOOCTADIENE - BUTADIENE	300,000	D	3
N-BUTYL ALCOHOL - ZIEGLER PROCESS	300,000	C	3
METHYL ETHYL KETONE - FROM S-BUTYL ALCOHOL	300,000	B	3
P-XYLENE	200,000	B	2
ISOPHORONE	100,000	D	3
METHYL CHLORIDE - METHANOL	100,000	B	3
DIETHYLENE GLYCOL	100,000	B	3
ISOPRENE - PETROLEUM FRACTIONS	100,000	D	3
SULFOLANE	90,000	D	3
1,1,1-TRICHLOROETHANE - ETHANE CHLORINATION	50,000	C	3
BENZENE - OTHER	40,000	C	3
ALKYLNAPHTHALENE	30,000	C	3
POLYETHYLENE GLYCOLS	10,000	C	3
CUMENE		B	2

[a] Impact factors have been multiplied by a scaling factor of 10^6 to avoid dealing with numbers much less than 1.0.

[b] Uncertainty level (see page 17).

[c] Type of calculation (degree of data aggregation):

1 = aggregated according to population;
2 = aggregated on a state basis;
3 = detailed plant data.

PESTICIDE MANUFACTURING SOURCE TYPES

Source Definition

The pesticide manufacturing industry produces a variety of chemical compounds used as pesticides. In some instances, as many as eight different processes are used to manufacture a specific pesticide, none of these being identified by plant or producer (11). Many of the production operations as well as actual production statistics in the industry are proprietary, making descriptive process data either quite limited or not available.

For many pesticides with similar chemical structures, production processes are similar. For other pesticides derived from a common raw material, processes are also similar. For prioritization purposes, the pesticide industry was divided into the following 11 categories (12). Similarities between chemical structures and common raw input materials provide the basis for these divisions.

- Anilides
- Carbamates
- Chlorinated hydrocarbons
- Diene-based compounds
- Nitrated hydrocarbons
- Organoarsenicals and organometallics
- Organophosphorus
- Other nitrogenous compounds
- Triazines
- Ureas and uracils
- All others

Data Acquisition and Input Format

Available data concerning raw wastewater characteristics for organic pesticide manufacturers, as shown in Table 12 (12), were used as a starting point. These data were then complemented with data extracted from the development Document for Interim Final Effluent Limitations, Guidelines, and Proposed New Source Performance Standards for the Pesticide Industry (draft report) (13).

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(11) Honea, F. I. Industrial Process Profiles for Environmental Use: Chapter 8, Pesticides Industry, T. B. Parsons, ed. EPA-600/2-77-023h (PB 266 225), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, January 1977. 240 pp.

(12) Kelso, G. L., R. R. Wilkinson, and T. L. Ferguson. The Pollution Potential in Pesticide Manufacturing--1976. Contract 68-02-1324, Task 43, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. (Draft final report submitted to the EPA by Midwest Research Institute, 16 April 1976). 236 pp.

(13) Train, R. E., A. W. Breidenbach, E. C. Beck, R. B. Schaffer, J. S. Vitalis, and G. M. Jett. Development Document for Interim Final Effluent Limitations, Guidelines, and Proposed New Source Performance Standards for the Pesticide Industry. U.S. Environmental Protection Agency, Washington, D.C., August 1976 draft. 207 pp.

TABLE 12. RAW WASTEWATER CHARACTERISTICS OF ORGANIC PESTICIDE MANUFACTURERS (12)

Pesticides	Wastewater characteristics, g/m^3									
	pH	COD	BOD$_5$	Total solids	Suspended solids	Chlorides	Sulfates	Phosphates	Organic nitrogen	Pesticides and other wastes
Chlorinated pesticides	0.5	3,600	2,000	62,000	10	50,000	8,000			Phenol and cresol, 10 ppm; chlorophenols and chlorocresols, 100 ppm; chlorophenoxyacetic acids, 100 ppm; alcohols, 1,000 ppm.
Carbamates	7 to 10	10,000	Nil	40,000	Nil	100	20,000	Nil	500	Sodium, 8,000 ppm; carbamates, nil.
Parathion and methyl parathion	2	3,000	700	27,000		7,000	3,000	250	20	Sodium, 6,000 ppm; parathion, 20 ppm.
Diolefin-based chlorinated hydrocarbons	2	500	50	1,000	100	High				Endrin, 100 ppb to 300 ppb.
2,4,5-T; 2,4-D; MCPA	0.5	8,300	6,300	104,000	2,500	52,000		Low	Low	2,4-T, up to 3,000 ppm; 2,4-D, 130 ppm is typical.
Carbaryl										Carbaryl, 0.1 ppm to 1.0 ppm.
Chlordane										Chlordane, 400 ppm; sodium hydroxide, 20,000 ppm.
MSMA										Arsenic, 0.7 ppm to 0.8 ppm.
Creosote										Phenolic materials, 800 ppm to 900 ppm.
Maneb										Sodium sulfate, manganese sulfate, and sodium trithiocarbamates combined, 9 lb/13 lb maneb product.
Endrin	3 to 4				500 to 800					Endrin, 100 ppb to 1,500 ppb (700 ppb average); carbon tetrachloride, 400 ppm; hexachloronorbornadiene, 30 ppb to 50 ppb; heptachloronobornene, 30 ppb to 50 ppb.
Toxaphene	3 to 5									Toxaphene, <6 ppb to 2,200 ppb.

Pesticides[a]	Wastewater flow, m^3/metric ton product	Wastewater characteristics, g/m^3											
						Total solids							
		COD	BOD$_5$	TOC	Oil	Suspended	Dissolved	Phenol	Total phosphorus	Chloride	NH_3-N	Total Kjeldahl nitrogen	Metal
Halogenated:													
A	24.3	810	120	550	3	48	1,550	0.5					
B	11.6	16,000	8,500				3,580	0.5					
B	11.6	14,400	3,300	8,000	4,300	100	115,000	200.0					
C	465.7					10							
D	100.9	400				450							
E	465.7					198							
F	167.8												
G	366.7	2,490	1,800	603	6	10	733	0.03					

(continued)

See footnotes at end of table, page 29.

TABLE 12 (continued)

Pesticides[a]	Wastewater flow, m^3/metric ton product	Wastewater characteristics, g/m^3											
						Total solids							
		COD	BOD_5	TOC	Oil	Suspended	Dissolved	Phenol	Total phosphorus	Chloride	NH_3-N	Total Kjeldahl nitrogen	Metal
Organophosphorus:													
H	125.2	3,110					7,130		51	2,260			
I	9.6	40,200					210,000		6,900	147,000			
J	69.8	3,150					9,420		304	6,500			
K	64.8	8,910					49,800		770	33,000	5,300		
L	13.9	3,850					58,500		1,170	44,000	20,200		
M	72.2	3,100					16,600		115	5,700			
N	8.7	42,000					125,000		4,260	75,000			
O	63.4	3,150					19,250		1,930	700	2,200		
P	57.7	2,160						340					
Q	49.9	3,600						255					
R	50.0	4,100		1,700			19,000	0.3	210	6,900			
S	3.2	19,700	540				86,000		19,000				
T	14.8	6,100											
U	36.5												
V	6.2												
W	1.7												
X	24.5												
Y	81.3												
Z	17.3	335	135	108	10	73	41,500	0.6	2		2		
AA	23.3	15,600	1,350	3,850	20	55	54,000	0.5	250	74,000	850	13	
BB	53.5	4,240	955	934	59	15	14,800	11	610		630	9,400	
S	3.2	12,500		6,830	7,200	36	79,000	36	2,150		250		
Organonitrogen:													
CC	90.0	4,740					44,300			13,700	318		
DD	50.3	1,480					6,400			4,400			
EE	52.4		820				19,900		178	18,800			
FF	55.3		840				36,700		190	25,300			
GG	11.6	800	300				20,000			450	13		
HH	6.5												
II	41.7	6,030								6,600	2,100		
JJ	58.2	3,900								2,500	288		
KK	11.7	14,300								23,000	1,500		
LL	4.9	7,150											
MM	23.3	2,650								3,900	80		
NN	60.2	770	350										
OO	38.8	1,800	750										
PP	80.0	1,680	495										
QQ	50.9	15,100	11,400										
RR	135.8	8,000	5,600										
SS	121.3	15,000	11,500										
TT	52.4	14,000	2,400	5,200	0.5	1,845	57,300		1,640		67		
GG	11.6	8,100	2,500	4,200	9.0	200	38,800		250	2,600	250		
UU	112.5	2,300	1,155	420		10	2,000				1,020		
VV	104.8	2,300	1,160	420	81	11	2,000				910		
Metallo-organic:													
WW	73.6	2,200	790			3,170							715 (Mn)
XX	77.6	1,500	670			1,645							450
YY	319.2	450	22	77	16	3,300	29,700				737	843	1,350 (Mn)

(continued)

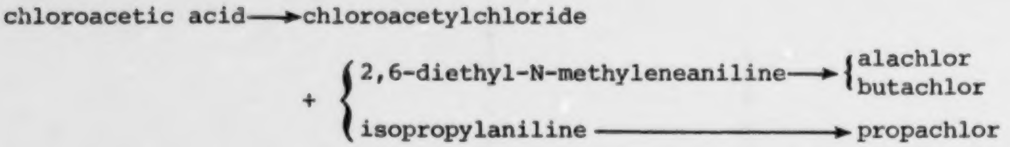
TABLE 12 (continued)

Note.— Blanks indicate data unavailable or undetermined.

[a] Pesticide identification:

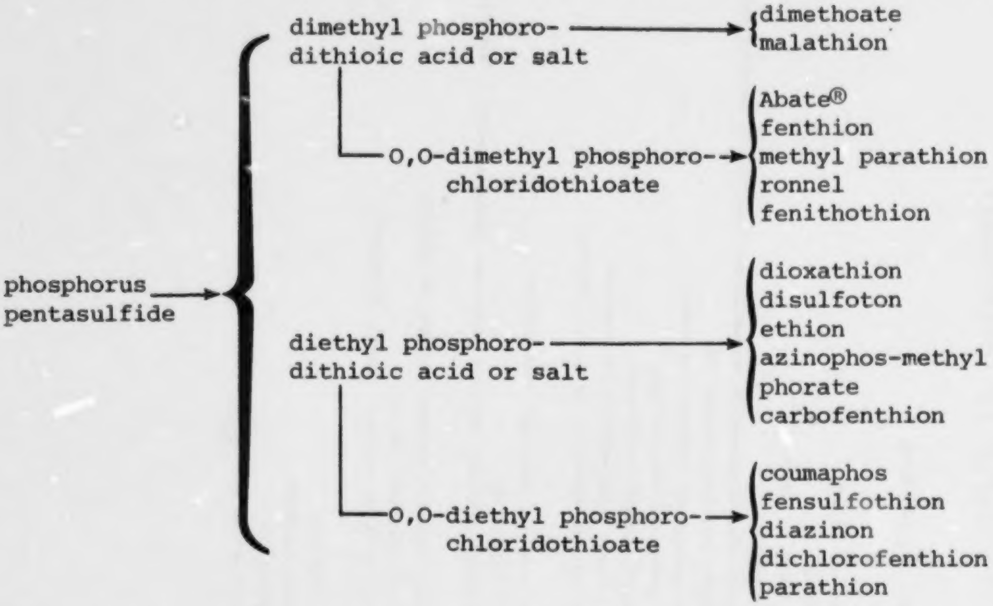
A--2,4-D; dalapon; or 2,4,5-T.
B--PCP or sodium PCP.
C, D, E--Heptachlor, endrin, or isodrin.
F, G--Heptachlor or endrin
H, I, J, K, L, M, N, O--Coumaphos, disulfoton, azinphosmethyl, methamidophos, fensulfothion, fenthion, demeton, or methyl demeton.
P, Q, R--Parathion, methyl parathion, or Niran 6-3.
S--Composite of chlorpyrilos, crufomate, and ronnel.
T--Composite of methyl parathion and Aspon.
U, V, W, X--Sterofos, meviphos, naled, or dichloros.
Y--Composite of fonfos, carbophenothion and bensulfide.
Z--Composite of sterofos, dichlorvos, naled, and meviphos.
AA--Diazinon
BB--Composite of coumaphos, disulfoton, azinphosmethyl.
CC, DD--Metribuzin or benzazimide.
EE, FF--Atrazine, simazine, propazine, ametryne, prometryne, simetryne, sumitol, terbatryne, prometone, or cynanazine.
GG--Dinoseb
HH--Burylate, EPTC, vernolate, cycloate, molinate, or pebulate.
II, JJ, KK, LL, MM--Alachlor, CDAA, propachlor, butachlor.
NN, OO, PP, QQ, RR, SS--Diuron, bromacil, thiram, methomyl, linuron, or terbacil.
TT--Atrazine
UU, VV--Alchlor or propachlor.
WW--Manganese dithiocarbamate.
XX--Zinc dithiocarbamate.
YY--Manganese dithiocarbamate.

Based on similarities between raw input materials, pesticides could be grouped and given the same effluent characterisitcs. For example, alachlor, butachlor, and propachlor were given similar prioritization input based on the following production chemistry:


chloroacetic acid → chloroacetylchloride
+
2,6-diethyl-N-methyleneaniline →
alachlor
butachlor
isopropylaniline → propachlor

(18)

Similarly, several organophosphorus insecticides may be grouped based on the following similarity in production chemistry:


phosphorus pentasulfide
dimethyl phosphorodithioic acid or salt
dimethoate
malathion
O,O-dimethyl phosphorochloridothioate
Abate®
fenthion
methyl parathion
ronnel
fenithothion
diethyl phosphorodithioic acid or salt
dioxathion
disulfoton
ethion
azinophos-methyl
phorate
carbofenthion
O,O-diethyl phosphorochloridothioate
coumaphos
fensulfothion
diazinon
dichlorofenthion
parathion

(19)

Where wastewater characteristics could not be estimated from the preceding methodology, average values were used from pesticides in the same category, or the compound was assumed to have the same wastewater characteristics as a pesticide with a similar chemical structure. Information regarding production, plant location, wastewater flow, and pollutant concentrations was derived from several sources (14-20).

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(14) Lawless, E. W., R. von Rümker, and T. L. Ferguson. Pesticide Study Series--5: The Pollution Potential in Pesticide Manufacturing (PB 213 782). Contract 69-01-0142, U.S. Environmental Protection Agency, Cincinnati, Ohio, June 1972. 249 pp.

(15) Ifeadi, C. N. Screening Study to Develop Background Information and Determine the Significance of Air Contaminant

Prioritization Listing

Table 13 alphabetically lists all pesticide source types that were prioritized in this study.

The pesticide water pollution listing was presented earlier in Table 2 and is repeated in Table 14. Several organophosphate pesticides ranked high due in part to their potentially high chloride concentrations and characteristic high toxicity. Atrazine was ranked towards the top of the list primarily due to a combination of high COD, TSS, TDS, and large annual production. DDT was excluded from the prioritization because all of its process wastewater is recycled.

FERTILIZER MANUFACTURING SOURCE TYPES

Source Definition

Sixteen effluent sources were designated for prioritization in the fertilizer manufacturing source category. These sources were categorized into four general groups: 1) phosphorus-based fertilizers, including sulfuric acid production, 2) nitrogen-based fertilizers, 3) fertilizer mixing plants, and 4) other fertilizers.

Emissions from Pesticide Plants. EPA-540/9-75-026 (PB 244 734), U.S. Environmental Protection Agency, Washington, D.C., March 1975. 85 pp.

(16) Meiners, A. F., C. E. Mumma, T. L. Ferguson, and G. L. Kelso. Wastewater Treatment Technology Documentation for Toxaphene Manufacture. EPA-440/9-76-013, U.S. Environmental Protection Agency, Washington, D.C., February 1976. 123 pp.

(17) von Rümker, R., E. W. Lawless, and A. F. Meiners. Production, Distribution, Use, and Environmental Impact Potential of Selected Pesticides (PB 238 795). Contract EQC-311, Council on Environmental Quality, Washington, D.C., March 1974. 439 pp.

(18) Ouellette, R. P., and J. A. King. Chemical Week Pesticides Register. McGraw-Hill Book Company, New York, New York, 1977. 346 pp.

(19) 1976 Farm Chemicals Handbook. Meister Publishing Co., Willoughby, Ohio, 1976. 577 pp.

(20) Patterson, J. W. State-of-the-Art for the Inorganic Chemicals Industry: Inorganic Pesticides. EPA-600/2-74-009a, U.S. Environmental Protection Agency, Washington, D.C., March 1975. 39 pp.

TABLE 13. ALPHABETICAL LISTING OF PESTICIDE SOURCE TYPES PRIORITIZED

Abate
Alachlor
Aldicarb
Amitrole
Aspon
Atrazine
Azinphos--methyl
Azodrin
Benefin
Benomyl
Bensulide
Bromacil
Butachlor
Butylate
Cacodylic acid
Captan
Carbaryl
Carbofuran
Carbophenothion
CDAA
CDEC
Chloramben
Chlorobenzilate
Chlordane
Chloroneb
Chlorpropham
Chlorpyrifos
Copper sulfate
Coumaphos
Crufomate
Cycloate
2,4-D
Dalapon
DDT
Deet
DEF
Diazinon
Dicamba
Dichlorofenthion
Dichlorvos
Dicofol
Dicrotophos
Dimethoate
Disulfoton
Dioxathion
Diuron
Endosulfan
Endrin
EPTC
Ethion
Fenac
Fenitrothion
Fensulfothion
Fenthion
Ferbam
Fluometron
Fonophos
Heptachlor
Lead arsenate
Lindane
Linuron
Malathion
Maneb
Metalkamate
Methomyl
Methoxychlor
Methyl demeton
Methyl parathion
Metribuzin
Mevinphos
Mocap
Molinate
Monuron
Nabam
Naled
Neburon
Nitralin
Parathion
PCNB
PCP
Pebulate
Phorate
Phosphamidon
Polyram
Prometone
Propachlor
Propanil
Propazine
Pyrethrins
Ronnen
Silvex
Simazine
Sodium chlorate
2,4,5-T
2,4,5-T salts
Tebuthiuron
TEPP
Terbacil
Terrazole
Thionazin
Toxaphene
Triallate
Trifluralin
Vernolate
Zineb

TABLE 14. PRIORITIZATION OF PESTICIDE SOURCES OF WATER POLLUTION

SOURCE TYPE	IMPACT FACTOR[a]	CL[b]	CALC[c]
PHORATE	600,000,000	D	3
ENDOSULFAN	300,000,000	D	3
DIMETHOATE	300,000,000	D	3
CHLORAMBEN	200,000,000	D	3
MALATHION	100,000,000	D	3
AZODRIN	90,000,000	D	3
DIAZINON	50,000,000	B	3
PARATHION	40,000,000	B	3
CHLOROBENZILATE	30,000,000	C	3
LINDANE	30,000,000	D	3
DICAMBA	30,000,000	D	3
PROPACHLOR	20,000,000	C	3
BUTACHLOR	20,000,000	D	3
ALACHLOR	20,000,000	C	3
MANEB	20,000,000	B	3
PCP	10,000,000	B	3
DISULFOTON	10,000,000	B	3
CDAA	10,000,000	C	3
BENSULIDE	10,000,000	D	3
CHLORDANE	10,000,000	C	3
ATRAZINE	10,000,000	D	3
CARBOPHENOTHION	9,000,000	D	3
AMITROLE	8,000,000	D	3
FONOPHOS	8,000,000	D	3
METHOXYCHLOR	7,000,000	D	3
SODIUM CHLORATE	7,000,000	B	3
DICOFOL	6,000,000	D	3
SILVEX	6,000,000	D	3
SIMAZINE	5,000,000	C	3
COPPER SULFATE	5,000,000	B	3
CHLORONEB	4,000,000	D	3
METHYL PARATHION	4,000,000	B	3
FENSULFOTHION	4,000,000	B	3
PROPAZINE	3,000,000	D	3
ETHION	3,000,000	D	3

(continued)

TABLE 14 (continued)

SOURCE TYPE	IMPACT FACTOR[a]	CL[b]	CALC[c]
2,4-D	3,000,000	C	3
DEF	3,000,000	D	3
PROMETONE	3,000,000	D	3
THIONAZIN	2,000,000	D	3
ABATE	2,000,000	D	3
AZINPHOS - METHYL	2,000,000	C	3
FENAC	1,000,000	D	3
DEET	1,000,000	D	3
2,4,5-TRICHLOROPHENOL	1,000,000	D	3
MOCAP	1,000,000	D	3
HEPTACHLOR	1,000,000	C	3
CAPTAN	900,000	D	3
NITRALIN	800,000	D	3
METHOMYL	800,000	D	3
PCNB	800,000	B	3
FERBAM	600,000	D	3
METRIBUZIN	600,000	B	3
2,4,5-T	500,000	C	3
BENOMYL	500,000	D	3
FENTHION	400,000	B	3
CARBARYL	300,000	C	3
2,4,5-T SALTS	300,000	C	3
RONNEL	300,000	C	3
DINOSEB	200,000	B	3
METALKAMATE	200,000	D	3
ALDICARB	100,000	D	3
DEMETON	100,000	C	3
DIOXATHION	100,000	D	3
LINURON	100,000	C	3
VERNOLATE	80,000	D	3
FENITROTHION	80,000	D	3
CARBOFURAN	70,000	D	3
TEPP	60,000	D	3
ENDRIN	60,000	B	3
CHLORPYRIFOS	50,000	C	3
EPTC	50,000	D	3
TERRAZOLE	50,000	C	3
DICHLOFENTHION	50,000	D	3
COUMAPHOS	50,000	C	3
TRIFLURALIN	30,000	D	3
BROMACIL	20,000	C	3
POLYRAM	20,000	D	3
MOLINATE	20,000	D	3
LEAD ARSENATE	20,000	D	3
DIURON	20,000	C	3
CYCLOATE	10,000	D	3
PEBULATE	10,000	D	3
TOXAPHENE	10,000	C	3
CHLORPROPHAM	10,000	D	3
TRIALLATE	10,000	D	3
PROPANIL	9,000	D	3
NABAM	9,000	D	3
METHYL DEMETON	7,000	C	3
ZINEB	5,000	B	3
CDEC	5,000	D	3
DIALLATE	5,000	D	3
CRUFOMATE	4,000	D	3
NALED	3,000	C	3
TERBACIL	3,000	D	3
DICROTOPHOS	2,000	D	3
TEBUTHIURON	2,000	C	3
DALAPON	2,000	C	3
BENEFIN	1,000	C	3
MONURON	1,000	D	3
PHOSPHAMIDON	1,000	D	3
FLUOMETRON	900	D	3
NEBURON	600	D	3
MEVINPHOS	500	C	3
DICHLORVOS	100	D	3
ASPON	90	D	3
BUTYLATE	80	D	3
PYRETHRINS	70	D	3
CACODYLIC ACID	60	D	3

[a] Impact factors have been multiplied by a scaling factor of 10^6 to avoid dealing with numbers much less than 1.0.

[b] Uncertainty level (see page 17).

[c] Type of calculation (degree of data aggregation):

1 = aggregated according to population;
2 = aggregated on a state basis;
3 = detailed plant data.

Data Acquisition and Input Format

Effluent data for fertilizer manufacturing processes were obtained from the following sources:

- Development Document for Effluent Limitations and New Source Performance Standards for the Basic Fertilizer Chemicals Segment of the Fertilizer Manufacturing Point Source Category (21).
- Original data supplied to the U.S. Environmental Protection Agency by industry, dated 1975-1976, to aid in updating effluent limitations.
- Inorganic Fertilizer and Phosphate Mining Industries--Water Pollution and Control (22).
- National Pollutant Discharge Elimination System (NPDES) and Florida Department of Environmental Regulation (DER) discharge permits.
- State of the Art: Military Explosives and Propellants Production Industry; Volume II, Wastewater Characterization (23).
- Study by the U.S. Department of the Interior addressing the characterization of a nitric acid plant effluent (24).
- Personal communications with industry.

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(21) Martin, E. E. Development Document for Effluent Limitations and New Source Performance Standards for the Basic Fertilizer Chemicals Segment of the Fertilizer Manufacturing Point Source Category. EPA-440/1-74-011a (PB 238 652), U.S. Environmental Protection Agency, Washington, D.C., March 1974. 168 pp.

(22) Fullah, H. T., and B. P. Faulkner. Inorganic Fertilizer and Phosphate Mining Industries--Water Pollution and Control (PB 206 154). Grant No. 12020 FPD, U.S. Environmental Protection Agency, Washington, D.C., September 1971. 225 pp.

(23) Patterson, J. W., J. Brown, W. Duckert, J. Polson, and N. I. Shapira. State of the Art: Military Explosives and Propellants Production Industry; Volume II, Wastewater Characterization. EPA-600/2-76/213b, U.S. Environmental Protection Agency, Cincinnati, Ohio, August 1976. 273 pp.

(24) Fairall, J. M. Tennessee Valley Authority, Wilson Dam, Alabama - Nos. 1 and 2 Nitric Acid Units, Tennessee River. U.S. Department of the Interior, Tennessee Valley Authority and Federal Water Pollution Control Administration, Cincinnati, Ohio, May 1966. 12 pp.

Water usage for process in this source category varied from minor quantities used to clean up spills and equipment in fertilizer mixing plants to extensive usage as process water, cooling water, scrubber fluid, and boiler water for some manufacturing processes. Available data showed that most fertilizer plants make more than one product and that wastewater streams are generally combined before treatment and/or discharge.

Waste streams from phosphate fertilizer plants are usually ponded in evaporation basins and are often reused as cooling water or scrubber water. Discharges occur only during periods of intense rainfall, if at all. An extensive telephone survey of the phosphate fertilizer industry revealed that only about 8% of these plants discharge any of their wastewaters. Therefore, a discharge quantity of zero was assigned to these plants for prioritization.

Prioritization input data for the ammonium nitrate and urea categories were calculated by analyzing original data submitted to EPA by industry, dated 1975-76, to aid in updating effluent limitations. EPA requested separate data for ammonium nitrate production and urea production. However, much of the data submitted was from a discharge common to ammonium nitrate and urea processes as well as from associated nitric acid and ammonia production. Assumptions were made to distribute the pollutants to prioritization categories of ammonium nitrate production, including associated nitric acid and ammonia production, and urea production, including associated ammonia production.

Prioritization input data for the nitric acid category were obtained by analysis of data characterizing effluent from a Tennessee Valley Authority (TVA) nitric acid plant and a nitric acid plant located at an Army munitions plant. Pollutant levels were very small. Therefore, the contribution of a nitric acid plant to effluent from an ammonium nitrate complex would be small.

Prioritization input data for the ammonia category were obtained from tables included in Reference 22. Data on recirculated cooling water at ammonia plants were not included in the input data.

As in the case of nitric acid, pollutant levels were not significant when compared to those from ammonium nitrate and urea production. Approximately 75% of the U.S. production of ammonia, 84% of the U.S. production of ammonium nitrate, and 76% of the U.S. production of urea are used as nitrogen fertilizers or as feedstock for other fertilizers. Approximately 79% of the U.S. production of nitric acid is used as feedstock for ammonium nitrate production. Effluents generated at nitrogen fertilizer complexes are not expected to vary from effluents generated by the same process where the product is used for purposes other than nitrogen fertilizers.

No data were found for effluents from other fertilizers and fertilizer mixing plants. The major sources of effluent water are believed to be rainwater runoff and plant cleanup, rather than the actual manufacturing process. Consequently, in this report these materials were assigned a discharge value of zero.

Prioritization Listing

Table 15 alphabetically lists all fertilizer source types that were prioritized in this study.

TABLE 15. ALPHABETICAL LISTING OF FERTILIZER SOURCE TYPES PRIORITIZED

- Ammonia
- Ammonium nitrate
- Ammonium phosphate
- Ammonium sulfate
- Fertilizer mixing--ammoniation-granulation plants
- Fertilizer mixing--bulk blending plants
- Fertilizer mixing--liquid mix plants
- Manganese sulfate
- Nitric acid
- Phosphate rock--drying, grinding, calcining
- Phosphoric acid--wet process
- Potash--potassium salts
- Sulfuric acid
- Superphosphate--normal
- Triple superphosphate
- Urea

Ther fertilizer water pollution listing was presented earlier in Table 3 and is repeated in Table 16. The priority listing was established on the basis of total annual production of each category in the United States, average quantities of wastewater discharged per ton of product, concentrations of the principal pollutant species, and hazard factors which were assigned to each pollutant. Hazard factors were based on drinking water standards, freshwater quality standards, and toxicity data which were adjusted to compensate for differences across these parameters.

TEXTILE SOURCE TYPES

Source Definition

For the purpose of prioritization, the textile industry was divided into 17 major categories corresponding to Major Group 22 of the Standard Industrial Classification Manual. Each major category was then categorized by process operation in order to determine the wastewater characteristics for the subcategory.

TABLE 16. PRIORITIZATION OF FERTILIZER SOURCES OF WATER POLLUTION

SOURCE TYPE	IMPACT FACTOR[a]	CL[b]	CALC[c]
AMMONIUM NITRATE	80,000,000	C	2
AMMONIA	60,000,000	C	2
UREA	50,000,000	C	2
NITRIC ACID	2,000,000	C	2
FERTILIZER MIXING - AMMONIATION - GRANULATION PLANTS		C	2
PHOSPHORIC ACID - WET PROCESS		C	2
FERTILIZER MIXING - LIQUID MIX PLANTS		C	2
SUPERPHOSPHATE - NORMAL		C	2
SULFURIC ACID		C	2
PHOSPHATE ROCK - DRYING, GRINDING, CALCINING		C	2
AMMONIUM PHOSPHATES		C	2
FERTILIZER MIXING - BULK BLENDING PLANTS		C	2
AMMONIUM SULFATE		C	3
TRIPLE SUPERPHOSPHATES		C	3
POTASH - POTASSIUM SALTS		C	3
MANGANESE SULFATE		C	3

[a] Impact factors have been multiplied by a scaling factor of 10^6 to avoid dealing with numbers much less than 1.0.

[b] Uncertainty level (see page 17).

[c] Type of calculation (degree of data aggregation):

1 = aggregated according to population;
2 = aggregated on a state basis;
3 = detailed plant data.

For example, the major category "Cotton Weaving Mills" was subcategorized using the following process operations:

- Slashing cotton yarn.
- Dyeing cotton yarn.
- Bleaching cotton yarn.
- Desizing woven cotton fabric.
- Scouring woven cotton fabric.
- Mercerizing woven cotton fabric.
- Dyeing woven cotton fabric.
- Printing woven cotton fabric.
- Bleaching woven cotton fabric.
- Special chemical finishing of woven cotton fabric.

Asbestos textile sources were not included in this prioritization since they are not part of SIC Major Group 22.

Data Acquisition and Input Format

The desired information for water prioritization, including total production from each operation, pollutant concentration in the wastewater, volume of wastewater, and number and location of plants, was determined from a variety of sources. The major sources include:

- 1972 Census of Manufactures (SIC Industry Groups 221 through 229) (25-30).
- 1972 Census of Manufactures (Water Use in Manufacturing) (31).
- Upgrading Textile Operations to Reduce Pollution; 1. In-Plant Control of Pollution (32).

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(25) 1972 Census of Manufactures, Industry Series (SIC Industry Groups 221, 222, 223, and 224), Weaving Mills. MC72(2)-22A, U.S. Department of Commerce, Bureau of the Census, Washington, D.C., January 1975. 35 pp.

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(32) Upgrading Textile Operations to Reduce Pollution; 1. In-Plant Control of Pollution. EPA-625/3-74-004, U.S. Environmental Protection Agency, Washington, D.C., October 1974. 118 pp.

- The Cost of Clean Water and Its Economic Impact (33).
- An Industrial Waste Guide to the Cotton Textile Industry (34).
- Chemical Use and Discharge in Carpet Piece Dyeing (35).
- The Textile Industry and the Environment-1973 (36).
- Chemical/Physical and Biological Treatment of Wool Processing Wastes (37).
- Upgrading Textile Operations to Reduce Pollution; 2. Wastewater Treatment Systems (38).

In developing discharge factors, several assumptions were made. Dyeing woven cotton fabric, for example, was assumed to have the same wastewater characteristics as dyeing woven wool fabric. Similar assumptions were made for operations such as bleaching, printing, and scouring, in order to generate discharge factors for cotton, wool, and manmade textile production. Data were derived for each subcategory and then summed on a production-weighted basis in order to obtain prioritization data for each of the 17 major categories.

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Prioritization Listing

Table 17 alphabetically lists textile source types that were prioritized in this study.

The textile water pollution listing was presented earlier in Table 4 and is repeated in Table 18.

TABLE 17. ALPHABETICAL LISTING OF TEXTILE SOURCE TYPES PRIORITIZED

- Coated fabrics not rubberized
- Cordage and twine
- Cotton finishing mills
- Cotton weaving mills
- Felt goods except woven fills and hats
- Finishing mills--N.E.C.
- Floor covering mills
- Knitting mills
- Lace goods
- Manmade fiber and silk finishing mills
- Manmade fiber and silk weaving mills
- Narrow fabric mills
- Nonwoven fabrics
- Paddings and upholstery filling
- Processed textile waste
- Textile goods--N.E.C.
- Thread mills
- Throwing and winding mills
- Tire cord and fabric
- Wool weaving and finishing mills
- Wool yarn mills
- Yarn mills except wool

TABLE 18. PRIORITIZATION OF TEXTILE SOURCES OF WATER POLLUTION

SOURCE TYPE	IMPACT FACTOR[a]	CL[b]	CALC[c]
KNITTING MILLS	1,000,000,000	D	2
MAN-MADE FIBER AND SILK FINISHING MILLS	1,000,000,000	D	2
THROWING AND WINDING MILLS	1,000,000,000	D	2
COTTON WEAVING MILLS	800,000,000	D	2
FELT GOODS EXCEPT WOVEN FELTS AND HATS	700,000,000	D	2
COTTON FINISHING MILLS	700,000,000	D	2
MAN-MADE FIBER AND SILK WEAVING MILLS	600,000,000	D	2
WOOL YARN MILLS	300,000,000	D	2
NONWOVEN FABRICS	200,000,000	D	2
FINISHING MILLS - N E C	70,000,000	D	2
FLOOR COVERING MILLS	30,000,000	D	2
YARN MILLS EXCEPT WOOL	30,000,000	D	2
WOOL WEAVING AND FINISHING MILLS	30,000,000	D	2
COATED FABRICS NOT RUBBERIZED	10,000,000	D	2
NARROW FABRIC MILLS	8,000,000	D	2
TIRE CORD AND FABRIC	3,000,000	D	2
PROCESSED TEXTILE WASTE	2,000,000	D	2
PADDINGS AND UPHOLSTERY FILLING	2,000,000	D	2
CORDAGE AND TWINE	1,000,000	D	2
TEXTILE GOODS - N E C	900,000	D	2
THREAD MILLS	200,000	D	2
LACE GOODS	200,000	D	2

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[a] Impact factors have been multiplied by a scaling factor of 10^6 to avoid dealing with numbers much less than 1.0.

[b] Uncertainty level (see page 17).

[c] Type of calculation (degree of data aggregation):

1 = aggregated according to population;
2 = aggregated on a state basis;
3 = detailed plant data.

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APPENDIX A

DERIVATION OF A WATER POLLUTION SEVERITY MODEL

DIRECT WATER DISCHARGES

If a plant is discharging through multiple outfalls (and neglecting outfall or diffuser geometries), then the severity for a specific pollutant can be summed. Figure A-1 shows an example situation. Outfall 1 has a pollutant concentration, cd_1, and discharge flow rate, vd_1. Outfall 2 concentration and flow are cd_2 and vd_2, respectively.

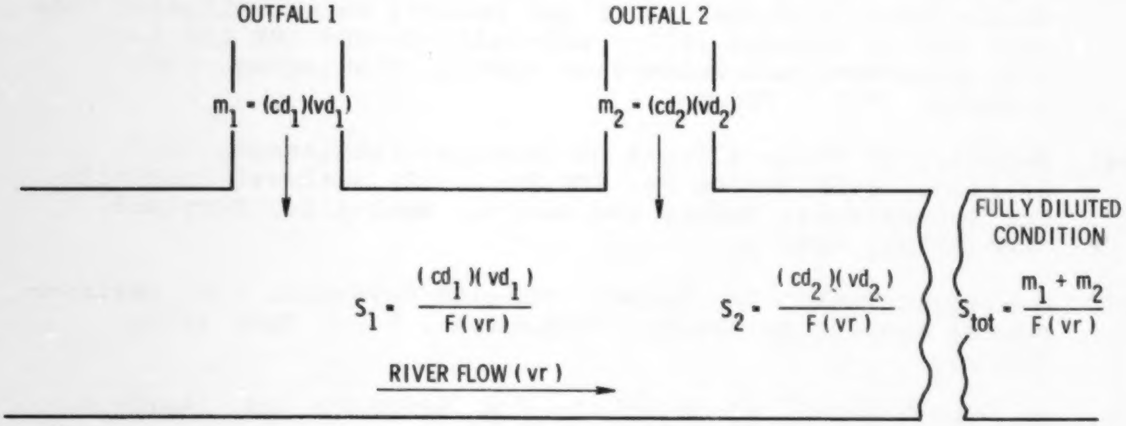
OUTFALL 1
OUTFALL 2
$m_1 = (cd_1)(vd_1)$
$m_2 = (cd_2)(vd_2)$
FULLY DILUTED CONDITION
$S_1 = \frac{(cd_1)(vd_1)}{F(vr)}$
$S_2 = \frac{(cd_2)(vd_2)}{F(vr)}$
$S_{tot} = \frac{m_1 + m_2}{F(vr)}$
RIVER FLOW (vr)

Figure A-1. Sample outfall geometry for pollutant with hazard factor, F.

The corresponding aftermixing zone severities are

$$S_1 = \frac{(cd_1)(vd_1)}{F(vr)} \tag{A-1}$$

and

$$S_2 = \frac{(cd_2)(vd_2)}{F(vr)} \tag{A-2}$$

(assuming vr is much greater than vd)

where F = hazard factor
vr = river flow rate

Pollutant mass discharge rates are

$$m_1 = (cd_1)(vd_1) \tag{A-3}$$

and

$$m_2 = (cd_2)(vd_2) \tag{A-4}$$

These mass discharge rates are additive. Fully diluted, the resulting concentration, c, is

$$c = \frac{m_1 + m_2}{vr} \tag{A-5}$$

and the total severity, S_{tot}, is

$$S_{tot} = \frac{c}{F} \tag{A-6}$$

$$= \frac{1}{F}\left(\frac{m_1 + m_2}{vr}\right) \tag{A-7}$$

$$= \frac{1}{F}\left[\frac{(cd_1)(vd_1)}{vr} + \frac{(cd_2)(vd_2)}{vr}\right] \tag{A-8}$$

$$= \frac{(cd_1)(vd_1)}{F(vr)} + \frac{(cd_2)(vd_2)}{F(vr)} \tag{A-9}$$

or

$$S_{tot} = S_1 + S_2 \tag{A-10}$$

Multiple, leachable, solid waste piles may also exist. These are treated as analogous to outfalls, and the solid waste contribution is added to the direct water discharges. Figure A-2 shows a sample configuration.

As in the previous example, S_1' and S_2' represent the aftermixing zone severity for Outfalls 1 and 2, respectively, S_3' and S_4' represent the aftermixing zone severity for leachable, solid waste Piles 1 and 2, respectively, or

$$S_3' = \frac{m_3}{F(vr)} \tag{A-11}$$

$$S_4' = \frac{m_4}{F(vr)} \qquad \text{(A-12}$$

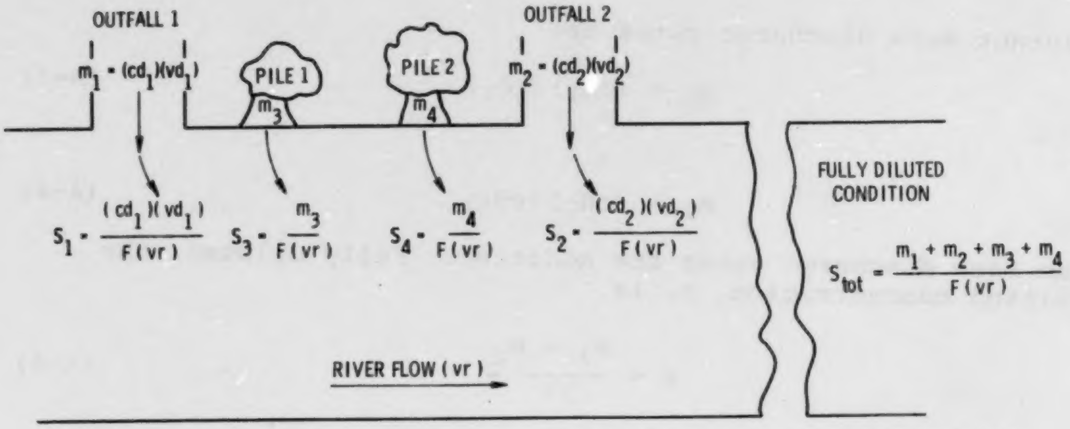
OUTFALL 1
$m_1 = (cd_1)(vd_1)$
PILE 1
m_3
PILE 2
m_4
OUTFALL 2
$m_2 = (cd_2)(vd_2)$
$S_1 = \frac{(cd_1)(vd_1)}{F(vr)}$
$S_3 = \frac{m_3}{F(vr)}$
$S_4 = \frac{m_4}{F(vr)}$
$S_2 = \frac{(cd_2)(vd_2)}{F(vr)}$
FULLY DILUTED CONDITION
$S_{tot} = \frac{m_1 + m_2 + m_3 + m_4}{F(vr)}$
RIVER FLOW (vr)

Figure A-2. Sample outfall and solid waste leaching model.

where m_3 and m_4 represent the pollutant mass discharge rate from Piles 1 and 2, respectively. Total severity due to both outfalls and both piles is thus

$$S'_{tot} = S'_1 + S'_2 + S'_3 + S'_4 \qquad \text{(A-13)}$$

where S'_{tot} = total severity resulting from various outfalls and leachable, solid waste piles after full dilution

$S'_1 \ldots S'_4$ = aftermixing zone severity for specific outfall or leachable, solid waste pile

Generalizing this approach for any pollutant discharged from any plant with multiple outfalls and leachable solid waste piles gives

$$S_{ij} = \frac{mw_{ij} + ms_{ij}}{F_i(vr_j)} \qquad \text{(A-14)}$$

where S_{ij} = severity for the ith pollutant at the jth plant

and

$$mw_{ij} = \sum_{\ell=1}^{P} \left(vd_{j\ell}\right)\left(cd_{ij\ell}\right) \qquad \text{(A-15)}$$

where mw_{ij} = direct water mass discharge rate for the ith species at the jth plant

$vd_{j\ell}$ = discharge flow rate of the ℓth outfall at jth plant

$cd_{ij\ell}$ = concentration of the ith species in the ℓth outfall at the jth plant

P = number of discharging outfalls

Solid waste contribution due to solid leaching is defined as

$$ms_{ij} = \sum_{k=1}^{Q} \left(SW_{jk}\right)\left(f_{1j}\right)\left(f_{2ijk}\right) \qquad \text{(A-16)}$$

where ms_{ij} = water mass discharge rate due to solid residue leaching for the ith species at the jth plant

SW_{jk} = solid waste generation rate in the kth pile at the jth plant

Q = number of leachable piles

$f_{1j} = \alpha e^{\beta R_{j}(th)}$; leachable residue fraction (A-17)

α and β = dimensionless constants (intended to maintain total solids under 50×10^3 g/m^3 or 50 g/liter)[a]

R_j = rainfall rate at the jth plant, m/yr

$f_{2ijk} = (1 - wf_{jk})\ cf_{ijk}$; fraction of the ith constituent on a wet basis in the kth pile at the jth plant (A-18)

wf_{jk} = fraction of water in the kth pile at the jth plant

cf_{ijk} = fraction of the ith constituent on a dry basis in the kth pile at the jth plant

Combining the direct water discharge and the solid residue contribution results in

$$md_{ij} = mw_{ij} + ms_{ij} \qquad \text{(A-19)}$$

where md_{ij} = combined mass discharge rate for the ith species at the jth plant

and

$$S_{ij} = \frac{md_{ij}}{F_i\left(vr_j\right)} \qquad \text{(A-20)}$$

where vr_j = river flow rate at the jth plant

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[a] Above 50 g/m^3, the resulting solution would not flow readily (personal communication with G. Nelson, U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Cincinnati, Ohio, 1975). Assuming a maximum annual rainfall of 1.7 m, α was set equal to 1.723×10^{-4} and β to 1.48. The choice of α and β as constants implies that all materials in a solid waste are equally soluble. In reality α and β are variables that depend on the solubility of each species in the solid waste, and further refinements of the prioritization model should take this into consideration.

If a final aftermixing zone concentration, c_{ij}, is defined as

$$c_{ij} = \frac{md_{ij}}{vr_j} \tag{A-21}$$

then the severity for the ith pollutant at the jth plant is simply

$$S_{ij} = \frac{c_{ij}}{F_i} \tag{A-22}$$

OXYGEN DEMAND MODEL

The oxygen demand model is also composed of two streams, the direct water discharge oxygen demand and the solid residue portion of the oxygen demand. The water discharge oxygen demand is calculated as

$$mow_j = \sum_{\ell=1}^{P} \left(vd_{j\ell}\right)\left(TODw_{j\ell}\right) \tag{A-23}$$

where mow_j = oxygen deficit rate of direct water discharges at the jth plant
$TODw_{j\ell}$ = total oxygen demand of the direct water discharge in the ℓth outfall at the jth plant. (See Appendix B for a further description.)

The solid residue portion of the oxygen demand is calculated as

$$mos_j = \sum_{k=1}^{O} \left(TODs_{jk}\right)\left(f_{1j}\right) \tag{A-24}$$

where mos_j = oxygen deficit rate of the solid residue leachate at the jth plant
$TODs_{jk}$ = total oxygen demand of the leachable solid residue in the kth pile at the jth plant
f_{ij} = leachable residue fraction

The total is simply the sum of the mass dicharge rates.

$$mod_j = mow_j + mos_j \tag{A-25}$$

where mod_j = total oxygen deficit rate at the jth plant

The oxygen deficit severity, So_j, is defined by

$$So_j = \left(\frac{mod_j}{vr_j}\right)\left(\frac{1}{cs_j - DO}\right) \qquad \text{(A-26)}$$

where cs_j = saturated dissolved oxygen concentration at the jth plant receiving stream
DO = dissolved oxygen freshwater quality criterion

subject to

$$(cs_j - DO) = \begin{Bmatrix} (cs_j - DO) \text{ if } (cs_j - DO) \geq 1.0 \\ 1.0 \text{ if } (cs_j - DO) < 1.0 \end{Bmatrix} \qquad \text{(A-27)}$$

If co_j is defined as the final aftermixing zone oxygen demand concentration at the jth plant,

$$co_j = \frac{mod_j}{vr_j} \qquad \text{(A-28)}$$

and if F_{oj} is defined as the hazard factor of the oxygen demand at the jth plant,

$$F_{oj} = cs_j - DO \qquad \text{(A-29)}$$

then the oxygen demand severity at the jth plant, So_j, is

$$So_j = \frac{co_j}{F_{oj}} \qquad \text{(A-30)}$$

WATER IMPACT MODEL

As mentioned in the main body of the report, a water impact factor was defined by first aggregating individual pollutant severities for each plant:

$$S_j = \left[(So_j)^2 + \sum_{i=1}^{N} (S_{ij})^2\right]^{1/2} \qquad \text{(A-31)}$$

The water impact factor, Iw_x, was then defined as the sum of the plant severities for Z plants in source type x.

$$Iw_x = \sum_{j=1}^{Z} S_j \qquad \text{(A-32)}$$

or

$$Iw_x = \sum_{j=1}^{Z}\left[\left(So_j\right)^2 + \sum_{i=1}^{N}\left(S_{ij}\right)^2\right]^{1/2} \qquad \text{(A-33)}$$

USE OF WEIGHTING FACTORS

Two weighting factors were developed, but they were not used due to insufficient data. The first weighting factor took into account the ambient concentration of a discharged species in the receiving body of water.

$$Wl_{ij} = \frac{ca_{ij}}{F_i} \qquad \text{(A-34)}$$

where ca_{ij} = ambient concentration of the ith species at the jth plant

The second weighting factor took into account biodegradability and ecological magnification (39).

$$W2_i = \frac{EM_i}{BI_i} \qquad \text{(A-35)}$$

where EM_i = ecological magnification factor for the ith discharged species
BI_i = biodegradability index for the ith species

The weighted impact factor $I'w_x$, was defined as follows:

$$I'w_x = \sum_{i=1}^{Z}\left[\left(So_j\right)^2 + \sum_{i=1}^{N}\left(Sw_{ij}\right)^2\left(Wl_{ij}\ W2_i\right)\right]^{1/2} \qquad \text{(A-36)}$$

subject to

$$\left(Wl_{ij}\ W2_i\right) = \begin{Bmatrix} \left(Wl_{ij}\ W2_i\right) \text{ if} \left(Wl_{ij}\ W2_i\right) \geq 1.0 \\ 1.0 \text{ if} \left(Wl_{ij}\ W2_i\right) < 1.0 \end{Bmatrix} \qquad \text{(A-37)}$$

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(39) Metcalf, R. L., P. Lu, and I. P. Kapoor. Environmental Distribution and Metabolic Fate of Key Industrial Pollutants and Pesticides in a Model Ecosystem (PB 225 479). Illinois Water Resources Center, Urbana, Illinois, June 1973. 80 pp.

AVERAGING TIME CONSIDERATIONS

Except for the hazard factor, F, the terms in the severity equations for a discharged pollutant at a specific site are functions of time; i.e.,

$$S(t) = \left[\frac{vd(t)}{vr(t)}\right]\left[\frac{cd(t)}{F}\right] \qquad \text{(A-38)}$$

where S(t) = severity as a function of time
vd(t) = discharge flow rate as a function of time, m^3/s
cd(t) = discharge concentration as a function of time, g/m^3
vr(t) = river flow rate as a function of time, m^3/s

For any averaging time, T, the average severity, $\overline{S}_T$, is then

$$\overline{S}_T = \frac{1}{T}\int_{t_1}^{t_2} \left[\frac{vd(t)}{vr(t)}\right]\left[\frac{cd(t)}{F}\right] dt \qquad \text{(A-39)}$$

where $T = t_2 - t_1$

Equation A-39 can be rewritten in terms of a mass discharge rate as

$$\overline{S}_T = \frac{1}{T}\int_{t_1}^{t_2} \frac{md(t)}{[vr(t)][F]} dt \qquad \text{(A-40)}$$

where $md(t) = [vd(t)][cd(t)]$ (A-41)
= mass discharge rate as a function of time, g/s

In practice these parameters were not known as a function of time, and average values were used for computation. Thus

$$\overline{S}_T = \frac{(\overline{vd})(\overline{cd})}{(\overline{vr})(F)} \qquad \text{(A-42)}$$

or

$$\overline{S}_T = \frac{\overline{md}}{(\overline{vr})(F)} \qquad \text{(A-43)}$$

where $\overline{vd}$ = average discharge flow rate, m^3/s
$\overline{cd}$ = average discharge concentration, g/m^3
$\overline{md}$ = average mass discharge rate, g/s
$\overline{vr}$ = average river flow rate, m^3/s

Similar considerations apply to the equations for solid leachate and oxygen demand.

EXCESS DOSE CONCEPT

If severity is expressed as a function of time as in Equation A-38, it can be used to define the ratio of actual exposure to a pollutant, Ψ_A, relative to a potentially hazardous exposure, Ψ_H, or

$$\overline{S}_T = \frac{\Psi_A}{\Psi_H} \qquad \text{(A-44)}$$

The aftermixing zone concentration as a function of time, c(t), can be written as

$$c(t) = \left[\frac{vd(t)}{vr(t)}\right] cd(t) \qquad \text{A-45)}$$

The integral of this concentration gives the actual exposure, Ψ_A, from

$$\Psi_A = \int_{t_1}^{t_2} c(t)\, dt \qquad \text{(A-46)}$$

The potentially hazardous exposure is given by

$$\Psi_H = \int_{t_1}^{t_2} F\, dt \qquad \text{(A-47)}$$

or

$$\Psi_H = TF \qquad \text{(A-48)}$$

$$\overline{S}_T = \frac{\Psi_A}{\Psi_H} = \frac{\int_{t_1}^{t_2} c(t)\, dt}{\int_{t_1}^{t_2} F\, dt} = \frac{1}{TF} \int_{t_1}^{t_2} \left[\frac{vd(t)}{vr(t)}\right] cd(t)\, dt \qquad \text{(A-49)}$$

If a skin and gill absorption-retention coefficient, ar_s, that is independent of c(t) was assumed to exist for a given aquatic species, s, then severity is an indicator of excess dose.

$$D_A = (ar_s)\Psi_A \tag{A-50}$$

where D_A = actual delivered dose, g

ar_s = absorption-retention coefficient, m^3/s

In addition,

$$D_H = (ar_s)\Psi_H \tag{A-51}$$

where D_H = potentially hazardous dose, g

Severity can then be expressed as

$$\overline{S}_T = D_A/D_H \tag{A-52}$$

and is a measure of excess dose.

APPENDIX B

OXYGEN DEFICIT RELATIONSHIPS

RELATIONSHIP OF TOD, COD, AND BOD_5

The oxygen required by a stream is an indicator of the quantity of pollutants present. Several parameters are currently used to measure oxygen demand:

- Total oxygen demand (TOD).
- Chemical oxygen demand (COD).
- Biochemical oxygen demand (BOD).
- Total organic carbon (TOC).

Correlations between TOD, COD, BOD_5, and TOC for an industrial waste and a municipal waste were developed as listed below.

For an industrial waste,

$$TOD = (1.064 \pm 0.0301)COD \qquad \text{(B-1)}$$

For a municipal waste,

$$TOD = (1.271 \pm 0.094)COD \qquad \text{(B-2)}$$

or

$$= (2.885 \pm 0.265)BOD_5 \qquad \text{(B-3)}$$

or

$$= (3.831 \pm 0.604)TOC \qquad \text{(B-4)}$$

where BOD_5 = amount of dissolved oxygen consumed in 5 days by biological processes breaking down organic matter in an effluent

Supporting data are given in Tables B-1 and B-2. Figures B-1 and B-2 show the relationships of measurements reported by Clifford (40).

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(40) Clifford, D. A. Automatic Measurement of Total Oxygen Demand. In: Proceedings of the 23rd Annual Industrial Waste Conference, Part II, Purdue University, West Lafayette, Indiana, 1968. pp. 772-785.

TABLE B-1. ANALYSIS OF DOW CHEMICAL CO. PRIMARY EFFLUENT (40)[a]

TOD	COD	TOD/COD
490	430	1.14
380	360	1.06
480	450	1.07
380	370	1.03
330	330	1.00
320	330	0.97
440	430	1.02
430	430	1.00
530	400	1.33
410	400	1.03
490	450	1.09
370	360	1.03
370	350	1.06
440	410	1.07
450	430	1.05
570	470	1.21
520	770	1.11
440	380	1.16
460	390	1.18
430	390	1.10
450	430	1.05
500	460	1.09
420	400	1.05
410	400	1.03
480	430	1.12
470	440	1.07
460	410	1.12
430	370	1.16
340	370	0.92
460	470	0.98
490	460	1.07
330	370	0.89
410	430	0.95
400	410	0.98

[a] Units for TOD and COD are mg/liter.

TABLE B-2. ANALYSIS OF MIDLAND, MICHIGAN PRIMARY EFFLUENT (40)[a]

TOD	COD	BOD	TOC	$\frac{\text{TOD}}{\text{COD}}$	$\frac{\text{TOD}}{\text{BOD}_5}$	$\frac{\text{TOD}}{\text{TOC}}$	$\frac{\text{COD}}{\text{TOC}}$	$\frac{\text{BOD}_5}{\text{TOC}}$
230	225	80	55	1.02	2.88	4.18	4.09	1.45
195	160	75	45	1.22	2.60	4.33	3.56	1.67
190	135	70	45	1.41	2.71	4.22	3.00	1.56
220	170	75	65	1.29	2.93	3.38	2.62	1.15
155	105	50	40	1.48	3.10	3.88	2.63	1.25
200	165	65	55	1.21	3.08	3.64	3.00	1.18
190	150	75	55	1.27	2.53	3.45	2.73	1.36
215	165	75	55	1.30	2.87	3.91	3.00	1.36
175	110	50	40	1.59	3.50	4.38	2.75	1.25
200	160	65	55	1.25	3.08	3.64	2.91	1.18
230	215	80	65	1.07	2.88	3.54	3.31	1.23
195	170	75	60	1.15	2.60	3.25	2.83	1.25
220	175	80	55	1.26	2.75	4.00	3.18	1.45

[a] Units for TOD and COD are mg/liter.

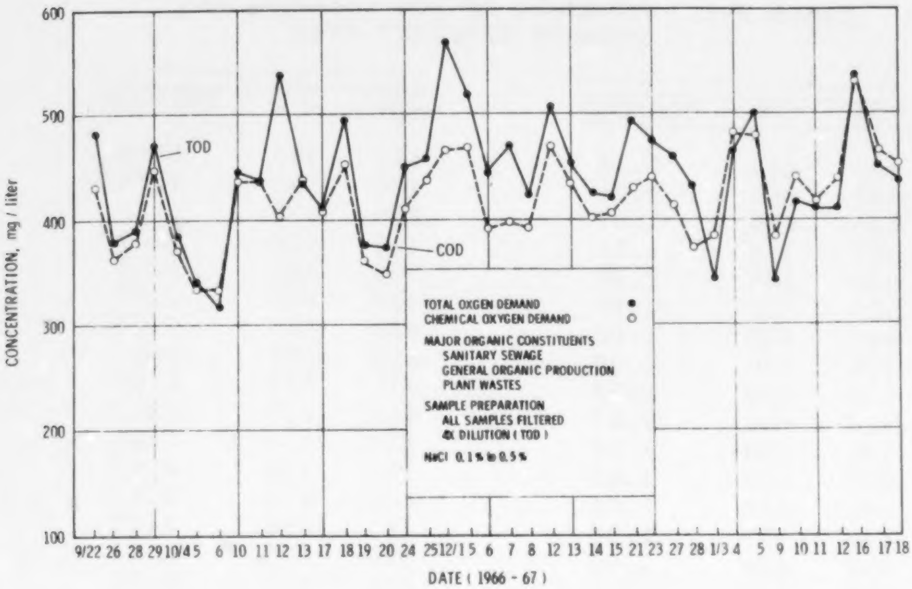

Figure B-1. Dow Chemical Co., primary effluent (40).[a]

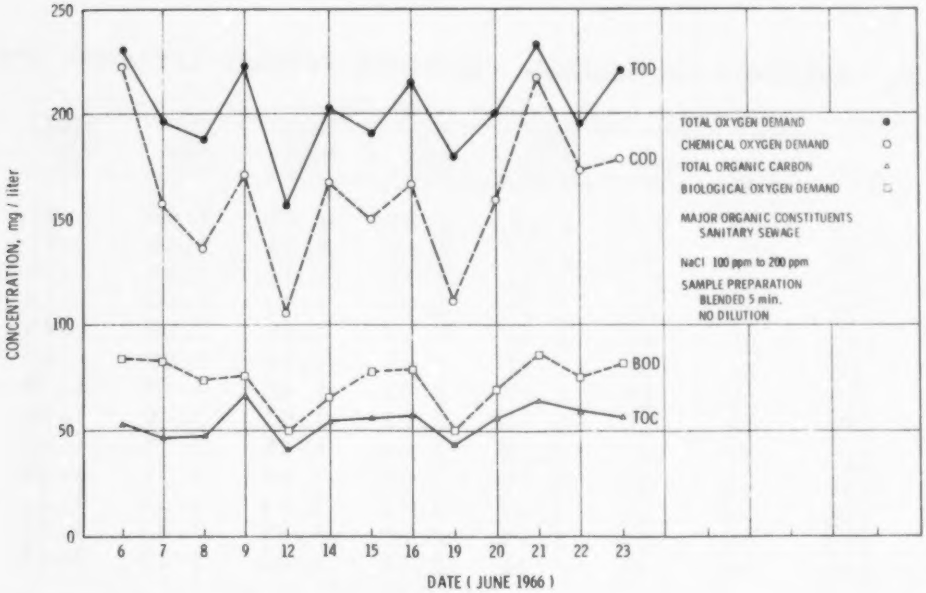

Figure B-2. Midland, Michigan, primary effluent (40).[a]

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[a] Units in Figures B-1 and B-2 are not metric SI but they do represent those units reported in the reference shown.

RELATIONSHIP BETWEEN BOD_5, TOD, AND BOD_L

A review of available literature revealed that a first order reaction relationship exists between BOD_5 and BOD_L (ultimate BOD); namely,

$$BOD_L = \frac{BOD_5}{1 - e^{-k't}} \qquad \text{(B-5)}$$

where BOD_L = ultimate BOD, mg/liter
e = natural base logarithm (2.72)
k' = BOD_5 rate constant, $days^{-1}$
t = time; for BOD_5, t = 5 days

The BOD rate constant, k', varies from 0.08 day^{-1} to 0.30 day^{-1} and is strictly dependent on the type of waste. For the two extreme cases, we have the equations developed below.

Case 1

If k' equals 0.30, then

$$BOD_L = \frac{BOD_5}{1 - e^{-(0.3)(5)}} \qquad \text{(B-6)}$$

$$= \frac{BOD_5}{0.777}$$

$$BOD_L = 1.29\ BOD_5$$

Case 2

If k' equals 0.08, then

$$BOD_L = \frac{BOD_5}{1 - e^{-(0.08)(5)}}$$

$$= \frac{BOD_5}{0.330}$$

$$BOD_L = 3.03\ BOD_5$$

TOD FOR OXYGEN-CONSUMING DISCHARGES

Based on the information above, the following options for TOD were used

$$\mathrm{TOD} = 1.3\ \mathrm{COD} \qquad (\mathrm{B}\text{-}8)$$

$$\mathrm{TOD} = 2.9\ \mathrm{BOD}_5 \qquad (\mathrm{B}\text{-}9)$$

$$\mathrm{TOD} = 3.8\ \mathrm{TOC} \qquad (\mathrm{B}\text{-}10)$$

The above factors were derived from data for a specific waste; i.e., Midland, Michigan, primary effluent. The relationship between TOD, BOD_5, COD, and TOC will not be valid for all types of wastes, but for this prioritization these factors were used.

Using a worst case basis, if more than one value is available, the oxygen demand-weighted equation producing the largest theoretical oxygen demand potential is used.

APPENDIX C

IMPACT FACTOR SAMPLE CALCULATION

This appendix provides an example of the detailed calculations used to compute the impact factor for the production of ethylene dichloride via the direct chlorination of ethylene (abbreviated as "ethylene dichloride-ethylene chlorination" in this report). The following steps are used to compute the impact factor:

1) Compute outfall effluent factors.
    - Species outfall effluent factors.
    - TOD outfall effluent factors.
    - Solid waste effluent factors.
2) Compute total annual effluent mass loading.
3) Compute source severity for each species at each plant.
4) Compute impact factor.

Data in Tables C-1, C-2, C-3, and E-1 (in Appendix E) contain the input necessary to compute the impact factor. The computation methodologies used in this sample calculation are described in Section 3, Appendix A, and Appendix B of this report.[a] The steps involved in computing impact factors are presented in Figure C-1 and described below.

Compute Outfall Factors

Outfall effluent factors (O_F) and the information needed to calculate solid waste factors (SW_F) are presented in Table C-1. Section 4 of this report gives the rationale used to generate the outfall effluent factors.

TOD is treated as a discharged species but Table C-1 shows no (outfall) effluent factor for it, which indicates the value is unknown. Utilizing the methods developed in Appendix B, the TOD outfall effluent factor can be computed from the outfall effluent factors for COD, BOD, and TOC as follows:

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[a] English engineering units are used in the example for expediency. Units are converted to metric for comparison with values presented in other sections of this report.

TABLE C-1. DISCHARGE DATA FOR SAMPLE CALCULATION FOR ETHYLENE DICHLORIDE-ETHYLENE CHLORINATION

Material discharged	Hazard factor, g/m^3	Outfall effluent factor, lb/ton	Fraction of solid waste on a dry basis
TOD	0	0	0
COD	0	9.86	0
BOD	0	19.9	0
TOC	0	1.78	0
Phenol	0.001	0.00006	0
Ammonia nitrogen (as N_2)	0.02	0.00473	0
Total Kjeldahl nitrogen (as N_2)	0.02	0.01143	0
Cyanide	0.005	0.00034	0
Sulfate	250	192	0
Oil and grease	0.7	0.0557	0
Total phosphates	0.001	0.00022	0
Zinc	5	0.0001	0
Copper	1	0.0004	0
Iron	0.3	0.0096	0
Chromium	0.05	0.0011	0
Cadmium	0.01	0.00016	0
Total suspended solids	25	11.7	0
Total dissolved solids	250	195	0
Ethylene dichloride	1.53	5.8	0.228
Hydrogen chloride	0.543	7.6	0
Vinyl chloride	39.6	1.2	0
Methyl chloride	0.068	0.1	0
Ethyl chloride	202	0.1	0
Sodium hydroxide	250	120	0
Sodium chloride	250	0.4	0
Chloride	0.01	128	0
Mercuric hydroxide	0.004	0	0.00055
1,1,2-Trichloroethane	1.3	0	0.386
Tetrachloroethane	0.45	0	0.386

Solid waste discharge data:

Fraction of water in solid waste = 0.0

Solid waste generation rate for total industry = 200,000 tons/yr

TABLE C-2. PLANT DATA FOR SAMPLE CALCULATION FOR ETHYLENE DICHLORIDE-ETHYLENE CHLORINATION

Plant No.	Specific plant	Capacity, tons/yr	State No.
1	Allied Chemical, Baton Rouge, LA	173,750	18
2	Conoco Chemical, Westlake, LA	288,750	18
3	Diamond Shamrock, Deer Park, TX	110,000	43
4	Dow Chemical, Freeport, TX	400,000	43
5	Dow Chemical, Plaquemine, LA	331,250	18
6	Dow Chemical, Oyster Creek, TX	275,000	43
7	Ethyl Corp., Baton Rouge, LA	175,000	18
8	Ethyl Corp., Pasadena, TX	130,000	43
9	Goodrich, Calvert City, KY	250,000	17
10	PPG Industries, Lake Charles, LA	300,000	18
11	Shell Chemical, Deer Park, TX	300,000	43
12	Shell Chemical, Norco, LA	219,250	18
13	Stauffer Chemical, Carson, CA	85,000	5
14	Texaco, Port Neches, TX	17,500	43
15	Union Carbide, Taft, LA	37,500	18
16	Union Carbide, Texas City, TX	37,500	43
Total		3,130,500	

TABLE C-3. STATE RIVER FLOW RATES AND RAINFALL DATA

State	State No.	No. of points	Flow rate, m^3/s Average	Flow rate, m^3/s Standard deviation	Reference No.	Rainfall, m/yr (41)
Alabama	1	82	130.82	288.61	42	1.495
Alaska	2	88	160.13	587.86	43	1.389
Arizona	3	107	43.64	119.84	44	0.179
Arkansas	4	70	295.91	1,601.60	45	1.232
California	5	515	26.25	74.08	46	0.426
Colorado	6	13	48.42	65.98	47	0.394
Connecticut	7	28	127.99	219.17	48	1.169
Delaware	8	16	1.70	3.11	49	1.022
Florida	9	14	283.17	218.04	50	1.306
Georgia	10	32	155.18	101.94	51	1.228
Hawaii	11		2.83	2.83	(arbitrarily assigned)	0.582
Idaho	12	35	254.85	269.01	52	0.292
Illinois	13	23	458.74	991.09	53	0.875
Indiana	14	22	577.95	1,030.73	54	0.984
Iowa	15	23	141.58	373.78	55	0.845

(continued)

TABLE C-3 (continued)

			Flow rate, m^3/s			
State	State No.	No. of points	Average	Standard deviation	Reference No.	Rainfall, m/yr (41)
Kansas	16	32	37.66	64.56	56	0.722
Kentucky	17	16	1,285.59	2,831.68	57	1.095
Louisiana	18	7	5,022.02	6,565.26	58	1.442
Maine	19	20	127.43	144.42	59	1.036
Maryland	20	11	209.56	351.13	60	1.028
Massachusetts	21	85	17.56	67.51	61	1.080
Michigan	22	11	1,022.24	1,707.51	62	0.796
Minnesota	23	115	35.00	95.43	63	0.659
Mississippi	24	21	1,557.43	3,709.51	64	1.257
Missouri	25	24	1,206.30	1,012.28	65	0.912
Montana	26	24	167.07	198.22	66	0.289
Nebraska	27	23	189.72	237.86	67	0.767
Nevada	28	15	50.97	105.34	68	0.219
New Hampshire	29	51	24.38	51.62	69	0.919
New Jersey	30	10	218.04	254.85	70	1.076
New Mexico	31	116	8.04	13.68	71	0.246
New York	32	28	526.70	1,625.39	72	0.952
North Carolina	33	130	20.95	42.19	73	1.091
North Dakota	34	91	28.88	113.27	74	0.410
Ohio	35	30	416.26	906.14	75	0.953
Oklahoma	36	57	79.29	150.93	76	0.757
Oregon	37	26	2,613.66	4,080.46	77	0.955
Pennsylvania	38	37	467.23	404.93	78	0.985
Rhode Island	39	85	17.56	67.51	61	1.027
South Carolina	40	38	135.92	113.27	79	1.324
South Dakota	41	35	135.92	237.86	80	0.464
Tennessee	42	24	2,143.60	4,239.03	81	1.168
Texas	43	53	96.28	60.31	82	0.932
Utah	44	23	111.57	150.36	83	0.385
Vermont	45	37	19.43	38.43	69	0.827
Virginia	46	15	73.62	99.11	84	1.135
Washington	47	195	237.32	821.19	85	0.714
West Virginia	48	26	354.53	622.97	86	0.976
Wisconsin	49	14	461.57	347.45	87	0.752
Wyoming	50	18	43.33	35.12	88	0.383

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(41) The World Almanac & Book of Facts, 1976. Newspaper Enterprise Association, Inc., New York, New York, 1975. p. 790.

(42) Water Resources Data for Alabama, Water Year 1975. USGS/WRD/HD-76/003 (PB 251 854), U.S. Geological Survey, Water Resources Division, University, Alabama, 1976. 391 pp.

(continued)

(continued)

(43) Water Resources Data for Alaska, 1975. USGS/WRD/AK-75/1 (PB 264 228), U.S. Geological Survey, Water Resources Division, Anchorage, Alaska, 1976. 424 pp.

(44) Water Resources Data for Arizona, 1975. USGS/WRD/HD-76/036 (PB 259 326), U.S. Geological Survey, Water Resources Division, Tucson, Arizona, 1976. 452 pp.

(45) Water Resources Data for Arkansas, 1975. USGS/WRD/HD-76/022 (PB 256 671), U.S. Geological Survey, Water Resources Division, Little Rock, Arkansas, 1976. 696 pp.

(46) Water Resources Data for California, 1975, Volumes 1 to 4. USGS/WRD/HD-76/059, 058, 043, and 044 (PB 264 474, PB 264 475, PB 264 476, PB 264 477), U.S. Geological Survey, Water Resources Division, Menlo Park, California, 1976. 1916 pp.

(47) Water Resources Investigations in Colorado, 1977. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(48) Water Resources Investigations in Connecticut, 1972. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(49) Water Resources Investigations in Delaware, 1976. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(50) Water Resources Investigations in Florida, 1974. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(51) Water Resources Investigations in Georgia, 1974. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(52) Water Resources Investigations in Idaho, 1973. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(53) Water Resources Investigations in Illinois, 1977. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(54) Water Resources Investigations in Indiana, 1972. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(55) Water Resources Investigations in Iowa, 1972. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(56) Water Resources Investigations in Kansas, 1972. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(57) Water Resources Investigations in Kentucky, 1976. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(58) Water Resources Investigations in Louisiana, 1973. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(59) Water Resources Investigations in Maine, 1972. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(60) Water Resources Investigations in Maryland, 1972. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(61) Water Resources Data for Massachusetts and Rhode Island, Water Year 1975. USGS/WRD/HD-76/056 (PB 262 801), U.S. Geological Survey, Water Resources Division, Boston, Massachusetts, 1976. 296 pp.

(62) Water Resources Investigations in Michigan, 1972. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(63) Water Resources Data for Minnesota, Water Year 1975. USGS/WRD/HD-76/039 (PB 259 952), U.S. Geological Survey, Water Resources Division, St. Paul, Minnesota, 1976. 523 pp.

(64) Water Resources Investigations in Mississippi, 1973. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(65) Water Resources Investigations in Missouri, 1976. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(66) Water Resources Investigations in Montana, 1976. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(67) Water Resources Investigations in Nebraska, 1972. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(68) Water Resources Investigations in Nevada, 1972. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(69) Water Resources Data for New Hampshire and Vermont, 1975. USGS/WRD/HD-76/057 (PB 262 800), U.S. Geological Survey, Water Resources Division, Boston, Massachusetts, 1976. 193 pp.

(70) Water Resources Investigations in New Jersey, 1972. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(71) Water Resources Data for New Mexico, 1975. USGS/WRD/NM-75/1 (PB 263 548), U.S. Geological Survey, Water Resources Division, Albuquerque, New Mexico, 1976. 616 pp.

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(72) Water Resources Investigations in New York, 1973. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(73) Water Resources Data for North Carolina, 1975. USGS/WRD/HD-76/011 (PB 251 869), U.S. Geological Survey, Water Resources Division, Raleigh, North Carolina, 1976. 441 pp.

(74) Water Resources Data for North Dakota, Water Year 1975. USGS/WRD/HD-76/046 (PB 259 277), U.S. Geological Survey, Water Resources Division, Bismarck, North Dakota, 1976. 442 pp.

(75) Water Resources Investigations in Ohio, 1972. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(76) Water Resources Investigations in Oklahoma, 1976. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(77) Water Resources Investigations in Oregon, 1977. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(78) Water Resources Investigations in Pennsylvania, 1974. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(79) Water Resources Investigations in South Carolina, 1972. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(80) Water Resources Investigations in South Dakota, 1976. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(81) Water Resources Investigations in Tennessee, 1974. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(82) Water Resources Investigations in Texas, 1972. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(83) Water Resources Investigations in Utah, 1974. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(84) Water Resources Investigations in Virginia, 1973. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(85) Water Resources Data for Washington, 1975. USGS/WRD/HD-76/033 (PB 259 197), U.S. Geological Survey, Water Resources Division, Tacoma, Washington, 1976. 700 pp.

(86) Water Resources Investigations in West Virginia, 1973. U.S. Department of the Interior, Geological Survey, Washington, D.C.

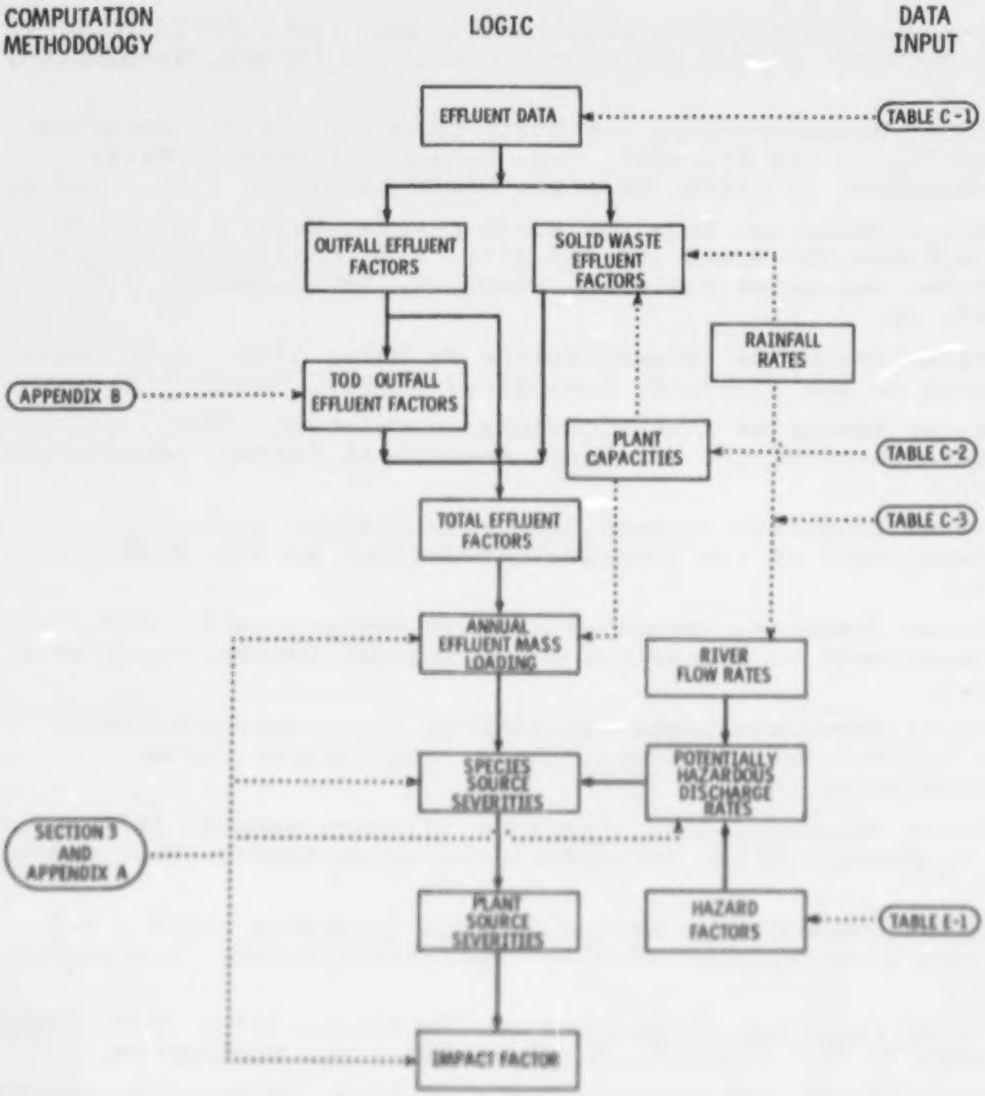
COMPUTATION METHODOLOGY
LOGIC
DATA INPUT
EFFLUENT DATA
TABLE C-1
OUTFALL EFFLUENT FACTORS
SOLID WASTE EFFLUENT FACTORS
RAINFALL RATES
APPENDIX B
TOD OUTFALL EFFLUENT FACTORS
PLANT CAPACITIES
TABLE C-2
TABLE C-3
TOTAL EFFLUENT FACTORS
ANNUAL EFFLUENT MASS LOADING
RIVER FLOW RATES
SPECIES SOURCE SEVERITIES
POTENTIALLY HAZARDOUS DISCHARGE RATES
SECTION 3 AND APPENDIX A
PLANT SOURCE SEVERITIES
HAZARD FACTORS
TABLE E-1
IMPACT FACTOR

Figure C-1. Steps involved in computing impact factor for a source type.

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(87) Water Resources Investigations in Wisconsin, 1976. U.S. Department of the Interior, Geological Survey, Washington, D.C.

(88) Water Resources Investigations in Wyoming, 1976. U.S. Department of the Interior, Geological Survey, Washington, D.C.

$$O_F(\text{TOD}) \equiv \max \begin{cases} 1.3 \text{ COD} \\ 2.9 \text{ BOD, lb/ton} \\ 3.8 \text{ TOC} \end{cases} \qquad \text{(C-1)}$$

From Table C-1, we have:

COD = 9.68 lb/ton
BOD = 19.9 lb/ton
TOC = 1.78 lb/ton

Using Equation C-1 we have

$$O_F(\text{TOD}) = \max \begin{cases} 1.3(9.68) = 12.6 \text{ lb/ton} \\ 2.9(19.9) = 57.7 \text{ lb/ton} \\ 3.8(1.78) = 6.76 \text{ lb/ton} \end{cases} \qquad \text{(C-2)}$$

Therefore, the TOD outfall effluent factor for this computation is 57.7 lb O_2/ton ethylene dichloride. The outfall effluent factors for COD, BOD, and TOC are only used to compute TOD; they are not used in any subsequent computations.

Solid waste composition is shown in Table C-1 under the column heading "fraction solid waste on a dry basis." Table C-1 also shows the total industry solid waste generation rate. The solid waste effluent factors are calculated as follows:

$$SW_{Fij} \equiv \left(\frac{SW_{tot}}{TC}\right)\left(1 - wf_j\right)\left(cf_{ij}\right) \alpha k_4 e^{\beta R_j} \qquad \text{(C-3)}$$

where SW_{Fij} = solid waste effluent factor for the ith species at the jth plant, lb/ton
TC = total industry capacity, tons/yr
SW_{tot} = total annual solid waste generation rate, tons/yr
wf_j = fraction of water in solid waste at the jth plant
cf_{ij} = fraction of the ith constituent on a dry basis in the solid waste at the jth plant
α = dimensionless constant = 1.723×10^{-4}
β = constant = 1.49 yr/m
R_j = rainfall rate at the jth plant, m/yr
k_4 = conversion factor = 2,000 lb/ton

The factor (SW_{tot}/TC) is the average solid waste generation factor for the industry. Unlike the outfall effluent factors in Table C-1, the solid waste effluent factors vary from plant to plant because R_j is different in each state. To illustrate the use of Equation C-3, SW_{Fij} is calculated for Plant 1 in Table C-2. Relevant input data are:

$$TC = 3.1305 \times 10^6 \text{ tons/yr}$$

$$SW_{tot} = 2 \times 10^5 \text{ tons/yr}$$

$$wf_j = 0$$

$$cf_{ij} = 0.228$$

$$R_j = 1.442 \text{ m (state of Louisiana)}$$

Species discharged = ethylene dichloride

Substituting these values into Equation C-3 gives

$$SW_{Fij} = \left(\frac{1}{3.13 \times 10^6}\right)(2 \times 10^5)(1 - 0)(0.228)$$

$$(1.723 \times 10^{-4})(2,000)e^{1.49(1.442)} \qquad \text{(C-4)}$$

$$= 4.24 \times 10^{-4} \text{ lb/ton}$$

The total effluent factor for each species is the sum of the outfall effluent factor and the solid waste effluent factor; i.e.,

$$E_{Fij} = O_{Fi} + SW_{Fij} \qquad \text{(C-5)}$$

where E_{Fij} = total effluent factor for the ith species at the jth plant, lb/ton

O_{Fi} = outfall effluent factor for the ith species, lb/ton

Thus, for the total ethylene dichloride discharge at Plant 1,

$$E_{Fij} = 5.8 + 0.000424 \qquad \text{(C-6)}$$

$$= 5.8 \text{ lb/ton}$$

Compute Total Annual Effluent Mass Loading for Each Species

The total annual effluent mass loading for each species from each plant is computed by multiplying the total effluent factor by the plant capacity, or:

$$X_{ij} = \left(E_{Fij}\right)\left(PC_j\right)\left(k_2\right) \qquad \text{(C-7)}$$

where X_{ij} = annual effluent mass loading for the ith species at the jth plant, g/yr
PC_j = plant capacity for the jth plant, tons/yr
k_2 = conversion factor = 454 g/lb

The total annual effluent mass loadings for TOD and ethylene dichloride from Plant 1 are as follows:

$$X(\text{TOD}) = (57.7)(173{,}750)(454) \tag{C-8}$$

$$= 4.55 \times 10^9 \text{ g/yr}$$

$$X(\text{ethylene dichloride}) = (5.8)(173{,}750)(454) \tag{C-9}$$

$$= 4.57 \times 10^8 \text{ g/yr}$$

Table C-4 shows the total annual effluent mass loadings for all species from all ethylene dichloride-ethylene chlorination plants as computed by the above methodology.

Compute Source Severity for Each Species at Each Plant

The source severity for each species from each plant is computed according to the methodology given in Section 3 of this report:

$$S_{ij} = \frac{X_{ij}}{vr_j \, F_i \, k_5} \tag{C-10}$$

where S_{ij} = water severity for ith pollutant at jth plant
vr_j = river flow rate at jth plant
F_i = hazard factor for ith species
k_5 = conversion factor, 3.154×10^7 s/yr

For TOD, the relationship is:

$$X_{oj} = vr_j(cs_j - DO)k_3 \tag{C-11}$$

where X_{oj} = total annual effluent mass loading for dissolved oxygen at the jth plant, g/yr
cs_j = saturated dissolved oxygen concentration at the jth plant = 11.3 g/m³ = 11.3 mg/liter (assumed for river water at 10°C)
DO = dissolved oxygen freshwater quality criterion = 5 g/m³ = 5 mg/liter

Tables C-3 and E-1 provide the annual average river flow rate for plant j and hazard factor for species i, respectively.

TABLE C-4. ANNUAL EFFLUENT MASS LOADINGS FOR MATERIALS DISCHARGED FROM ETHYLENE DICHLORIDE-ETHYLENE CHLORINATION PLANTS (10^6 g/yr)

Material discharged	Plant number[a,b]							
	1	2	3	4	5	6	7	8
TOD	4,550	7,560	2,880	10,500	8,670	7,200	4,580	3,400
Phenol	0.00473	0.00786	0.00299	0.0109	0.00902	0.00748	0.00476	0.00354
Ammonia nitrogen	0.373	0.620	0.236	0.858	0.711	0.590	0.375	0.279
Total Kjeldahl nitrogen	0.902	1.50	0.571	2.08	1.72	1.43	0.909	0.675
Cyanide	0.0268	0.0445	0.017	0.0617	0.0511	0.0424	0.0270	0.0200
Sulfate	15.1	25.1	9.58	34.8	28.8	23.9	15.2	11.3
Oil and grease	4.39	7.3	2.78	10.1	8.37	6.95	4.42	3.28
Total phosphate	0.0173	0.0288	0.0110	0.0399	0.0331	0.0274	0.0175	0.0130
Zinc	0.00788	0.0131	0.00499	0.0181	0.0150	0.0125	0.00794	0.0059
Copper	0.0315	0.0524	0.0200	0.0726	0.0601	0.0499	0.0318	0.0236
Iron	0.757	1.26	0.479	1.74	1.44	1.20	0.762	0.566
Chromium	0.0857	0.144	0.0549	0.20	0.165	0.137	0.0873	0.0649
Cadmium	0.0126	0.0210	0.00798	0.029	0.024	0.020	0.0127	0.00943
Total suspended solids	922	1,530	584	2,120	1,760	1,460	929	690
Total dissolved solids	15,400	25,500	9,730	35,400	29,300	24,300	15,500	11,500
Ethylene dichloride	457	760	289	1,050	871	723	460	342
Hydrogen chloride	599	995	379	1,380	1,140	948	603	448
Vinyl chloride	94.6	157	59.9	218	180	150	95.3	70.8
Methyl chloride	7.88	13.1	4.99	18.1	15.0	12.5	7.94	5.90
Ethyl chloride	7.88	13.1	4.99	18.1	15.0	12.5	7.94	5.90
Sodium hydroxide	94.6	157	59.9	218	180	150	95.3	70.8
Sodium chloride	31.5	52.4	20.0	72.6	60.1	49.9	31.8	23.6
Chlorine	10,100	16,800	6,390	23,200	19,200	16,000	10,200	7,550
Mercuric oxide	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
1,1,2-Trichloroethane	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Tetrachloroethane	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

(continued)

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[a] Plant numbers correspond to those shown in Table C-2.

[b] Values shown in table were determined using the methodologies contained in this report and do not represent actual plant data. Values calculated for specific plants may or may not coincide with actual values at each plant.

TABLE C-4 (continued)

Material discharged	9	10	11	12	13	14	15	16
	Plant number[a,b]							
TOD	6,540	7,850	7,850	5,740	2,230	458	982	982
Phenol	0.00680	0.00816	0.00816	0.00597	0.00231	0.00476	0.00102	0.00102
Ammonia nitrogen	0.536	0.644	0.644	0.470	0.182	0.0375	0.0805	0.0805
Total Kjeldahl nitrogen	1.30	1.56	1.56	1.14	0.441	0.0909	0.195	0.195
Cyanide	0.0386	0.0463	0.0463	0.0338	0.0131	0.00270	0.00578	0.00578
Sulfate	21.8	26.1	26.1	19.1	7.4	1.52	3.26	3.26
Oil and grease	6.32	7.58	7.58	5.54	2.15	0.442	0.947	0.947
Total phosphate	0.0249	0.0299	0.0299	0.0219	0.00824	0.00175	0.00374	0.00374
Zinc	0.0113	0.0136	0.0136	0.00995	0.00386	0.0794	0.0017	0.0017
Copper	0.0454	0.0544	0.0544	0.0398	0.0154	0.0318	0.0068	0.0068
Iron	1.09	1.31	1.31	0.955	0.370	0.0762	0.163	0.163
Chromium	0.125	0.150	0.150	0.109	0.0424	0.00873	0.0187	0.0187
Cadmium	0.0181	0.0218	0.0218	0.0459	0.617	0.00127	0.00272	0.00272
Total suspended solids	1,330	1,590	1,590	1,160	451	92.9	199	199
Total dissolved solids	22,100	26,500	26,500	19,400	7,520	1,550	3,320	3,320
Ethylene dichloride	658	789	789	577	224	46	98.7	98.7
Hydrogen chloride	862	1,030	1,030	756	293	60.3	129	129
Vinyl chloride	136	163	163	119	46.3	9.53	20.4	20.4
Methyl chloride	11.3	13.6	13.6	9.95	3.86	0.794	1.70	1.70
Ethyl chloride	11.3	13.6	13.6	9.95	3.86	0.794	1.70	1.70
Sodium hydroxide	136	163	163	119	46.3	9.53	20.4	20.4
Sodium chloride	45.4	54.4	54.4	39.8	15.4	3.18	6.8	6.8
Chlorine	14,500	17,400	17,400	12,700	4,940	1,020	2,180	2,180
Mercuric oxide	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
1,1,2-Trichloroethane	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Tetrachloroethane	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[a] Plant numbers correspond to those shown in Table C-2.

[b] Values shown in table were determined using the methodologies contained in this report and do not represent actual plant data. Values calculated for specific plants may or may not coincide with actual values at each plant.

For TOD and ethylene dichloride discharges at Plant 1 the following input data from step 2, Table C-3, and Table E-1 are needed to calculate severities:

Parameter	TOD	Ethylene dichloride
X_{ij}, g/yr	4.55×10^9	4.57×10^8
vr_j, m^3/s	5,022.02	5,022.02
F_i, g/m^3	NA[a]	1.53
cs_j, g/m^3	11.3	NA
DO, g/m^3	5.0 (89)	NA

[a] Not applicable.

The resulting source severities for TOD and ethylene dichloride at Plant 1 are as follows:

$$So = \frac{4.55 \times 10^9}{(5{,}022.02)(11.3 - 5)(3.15 \times 10^7)} \qquad (C\text{-}12)$$

$$= 0.00456$$

$$S(\text{ethylene dichloride}) = \frac{4.57 \times 10^8}{(5{,}022.02)(1.53)(3.154 \times 10^7)} \qquad (C\text{-}13)$$

$$= 0.00189$$

The above procedure is iteratively performed for all species from all plants. The results of these computations are shown in Table C-5.

Compute Impact Factor

The impact factor is computed using the following equation:

$$Iw_x = 10^6 \cdot \sum_{j=1}^{Z} S_j \qquad (C\text{-}14)$$

where Iw_x = overall water impact factor for entire industry

10^6 = constant[a]

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[a] The constant term, 10^6 is a scaling factor used to avoid dealing with numbers much less than 1.0.

(89) Standard Methods for the Examination of Water and Wastewater 13th Edition American Public Health Association, American Water Works Association, and Water Pollution Control Federation, Washington, D.C., 1971. 874 pp.

TABLE C-5. POLLUTANT SOURCE SEVERITIES FOR EACH PLANT

Material discharged	Plant number[a,b]							
	1	2	3	4	5	6	7	8
TOD	0.00456	0.00757	0.15	0.547	0.00868	0.376	0.00459	0.178
Phenol	0.00003	0.00005	0.00099	0.0036	0.00006	0.0025	0.00003	0.0012
Ammonia nitrogen	0.00012	0.00020	0.0039	0.0141	0.0002	0.0971	0.0001	0.0046
Total Kjeldahl nitrogen	0.0003	0.0005	0.0094	0.0342	0.0005	0.0235	0.0003	0.0111
Cyanide	0.00003	0.00006	0.0011	0.0041	0.00006	0.0028	0.00003	0.0013
Sulfate	<0.00001	<0.00001	0.00001	0.00004	<0.00001	0.00003	<0.00001	0.00001
Oil and grease	0.00004	0.00006	0.0013	0.0048	0.00008	0.0033	0.00004	0.0015
Total phosphate	0.00011	0.00018	0.0036	0.0131	0.0002	0.0090	0.0001	0.0043
Zinc	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Copper	<0.00001	<0.00001	<0.00001	0.00002	<0.00001	<0.00001	<0.00001	<0.00001
Iron	0.00002	0.00003	0.00053	0.0019	0.00003	0.00131	0.00002	0.00062
Chromium	0.00001	0.00002	0.00036	0.00131	0.00002	0.00090	0.00001	0.00043
Cadmium	<0.00001	0.00001	0.00026	0.00096	0.00002	0.00065	<0.00001	0.00031
Total suspended solids	0.00023	0.00039	0.00769	0.0279	0.00044	0.0192	0.00023	0.00908
Total dissolved solids	0.00039	0.00065	0.0128	0.0466	0.00074	0.0320	0.00039	0.0151
Ethylene dichloride	0.00189	0.00314	0.0623	0.226	0.0036	0.156	0.0019	0.0736
Hydrogen chloride	0.00696	0.0116	0.230	0.836	0.0133	0.575	0.00701	0.272
Vinyl chloride	0.00002	0.00003	0.00050	0.00181	0.00003	0.00124	0.00002	0.00059
Methyl chloride	0.00073	0.00122	0.0242	0.0878	0.00139	0.0604	0.00074	0.0285
Ethyl chloride	<0.00001	<0.00001	<0.00001	0.00003	<0.00001	0.00002	<0.00001	<0.00001
Sodium hydroxide	<0.00001	<0.00001	0.00008	0.00029	<0.00001	0.00019	<0.00001	0.00009
Sodium chloride	<0.00001	<0.00001	0.00003	0.00010	<0.00001	0.00007	<0.00001	0.00003
Chlorine	6.37	10.6	210	764	12.1	526	6.41	248
Mercuric oxide	<0.00001	<0.00001	0.00002	0.00007	<0.00001	0.00005	<0.00001	0.00002
1,1,2-Trichloroethane	<0.00001	<0.00001	0.00004	0.00015	<0.00001	0.00011	<0.00001	0.00005
Tetrachloroethane	<0.00001	0.00001	0.00012	0.00044	0.00001	0.00031	<0.00001	0.00015

(continued)

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[a] Plant numbers correspond to those shown in Table C-2.

[b] Values shown in table were determined using the methodologies contained in this report and do not represent actual plant data. Values calculated for specific plants may or may not coincide with actual values at each plant.

TABLE C-5 (continued)

Material discharged	Plant number[a,b] 9	10	11	12	13	14	15	16
TOD	0.0256	0.00787	0.410	0.00575	0.426	0.0239	0.000983	0.0513
Phenol	0.00017	0.00005	0.0027	0.00004	0.0028	0.0002	0.000006	0.00034
Ammonia Nitrogen	0.0007	0.0002	0.0106	0.0001	0.0110	0.0006	0.00002	0.0013
Total Kjeldahl nitrogen	0.0016	0.0005	0.0256	0.0004	0.0226	0.0015	0.00006	0.0032
Cyanide	0.0002	0.00006	0.0031	0.00004	0.0032	0.0002	0.00001	0.0004
Sulfate	<0.00001	<0.00001	0.00003	<0.00001	0.00004	<0.00001	<0.00001	<0.00001
Oil and grease	0.00022	0.00007	0.0036	0.00005	0.0037	0.00021	<0.00001	0.00045
Total phosphate	0.0006	0.0002	0.0098	0.0001	0.0102	0.0006	0.00002	0.0012
Zinc	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Copper	<0.00001	<0.00001	<0.00001	<0.00001	0.00002	<0.00001	<0.00001	<0.00001
Iron	0.00009	0.00003	0.00143	0.00002	0.00149	0.00008	<0.00001	0.00018
Chromium	0.00006	0.00002	0.00099	0.00001	0.00102	0.00006	<0.00001	0.00012
Cadmium	0.00004	0.00001	0.00072	0.00001	0.00075	0.00004	<0.00001	0.00009
Total suspended solids	0.00131	0.00040	0.0210	0.00029	0.0218	0.00122	0.00005	0.00262
Total dissolved solids	0.00218	0.00067	0.0349	0.00049	0.0363	0.00204	0.00008	0.00437
Ethylene dichloride	0.0106	0.00326	0.170	0.00238	0.176	0.00991	0.00041	0.0212
Hydrogen chloride	0.0391	0.0120	0.627	0.00878	0.651	0.0366	0.0015	0.0784
Vinyl chloride	0.00008	0.00003	0.00136	0.00002	0.00141	0.00008	<0.00001	0.00017
Methyl chloride	0.0041	0.00126	0.0659	0.00092	0.0684	0.00384	0.00016	0.00823
Ethyl chloride	<0.00001	<0.00001	0.00002	<0.00001	0.00002	<0.00001	<0.00001	<0.00001
Sodium hydroxide	0.00001	<0.00001	0.00022	<0.00001	0.00022	0.00001	<0.00001	0.00003
Sodium chloride	<0.00001	<0.00001	0.00007	<0.00001	0.00007	<0.00001	<0.00001	<0.00001
Chlorine	35.8	11.0	573.0	8.03	596	33.4	1.37	71.7
Mercuric oxide	<0.00001	<0.00001	0.00005	<0.00001	0.00003	<0.00001	<0.00001	<0.00001
1,1,2-Trichloroethane	<0.00001	<0.00001	0.00012	<0.00001	0.00006	<0.00001	<0.00001	0.00001
Tetrachloroethane	0.00003	0.00001	0.00034	0.00001	0.00017	0.00002	<0.00001	0.00004

[a] Plant numbers correspond to those shown in Table C-2.

[b] Values shown in table were determined using the methodologies contained in this report and do not represent actual plant data. Values calculated for specific plants may or may not coincide with actual values at each plant.

Z = number of plants
S_j = total water severity at the jth plant

S_j is the root mean sum of source severities for each species discharged from a plant. It is computed as follows:

$$S_j = \left[\left(So_j\right)^2 + \sum_{i=1}^{N} \left(S_{ij}\right)^2 \right]^{1/2} \qquad \text{(C-15)}$$

So_j and S_{ij} are computed as described in step 2.

The S_j values for each plant producing ethylene dichloride via the direct chlorination of ethylene are tabulated in Table C-6.

TABLE C-6. S_j FOR ALL PLANTS

Plant No.	S_j
1	6.37
2	10.6
3	210
4	764
5	12.1
6	525
7	6.41
8	245
9	38.8
10	11
11	573
12	8.03
13	596
14	33.4
15	1.37
16	71.7

$\sum S_j = 3{,}112.78$

The impact factor is

$$\begin{aligned} Iw_x &= 10^6 \cdot \sum S_j \qquad \text{(C-16)} \\ &= 10^6 \cdot 3{,}122.78 \\ &= 3{,}112{,}780{,}000 \\ &= 3{,}000{,}000{,}000 \text{ (rounded to one significant figure)} \end{aligned}$$

APPENDIX D

EXAMPLES OF INPUT DATA SHEETS

Examples of input data sheets are presented in Figures D-1 and D-2.

WATER PRIORITIZATION DATA SHEET

SOURCE DESCRIPTION ______________________ LOG NUMBER ________

RAW WASTEWATER LOADING ______________________ (gal/ton) UNCERTAINTY LEVEL ________

OPT*	Pollutant discharged	Hazard factor, mg/liter	Effluent rate, ton/yr	Effluent factor, lb/ton	Concen-tration, mg/liter	Ecological magnifica-tion	Biodegrad-ability index	Remarks

*OPT = Pollutant Option Indicator: TOD = 1, COD = 2, BOD = 3, TOC = 4

Figure D-1. Water prioritization data sheet.

SOURCE DESCRIPTION ______________________ LOG NUMBER __________

WASTE GENERATION RATE ______________________ (Units/Year)

AREA OF WASTE PILE ______________________

FRACTION OF WATER IN WASTE ______________________

Material	Fraction of waste material on dry basis	Hazard factor (mg/liter)	Remarks

Figure D-2. Solid waste to water prioritization sheet.

APPENDIX E

HAZARD FACTORS DEVELOPED FOR USE IN WATER PRIORITIZATION

The model used in prioritizing stationary water pollution sources was described in Section 3. This appendix describes the development of hazard factors for use in the prioritization model and presents hazard factors for various organic and inorganic chemical substances. A hazard factor, F, may be a water criterion or a calculated value.

Values were calculated by inserting toxicity values into a selected equation for F. Since specific toxicity indicators were not always available, several equations were required. The equations used are listed below in descending order of preference.

$$F_1 = 0.05 \times LC_{50} \text{ (96-hr) (Ref. 1)} \tag{E-1}$$

$$F_2 = 0.05 \times LC_{50} \text{ (48-hr or 24-hr)} \tag{E-2}$$

$$F_3 = 0.05 \times (LC_{Lo}, TC_{Lo}, IC_{50}) \tag{E-3}$$

$$F_4 = 2.25 \times 10^{-3} \times LD_{50} \text{ (oral/rat) (Ref. 2)} \tag{E-4}$$

$$F_5 = 2.25 \times 10^{-3} \times LD_{50} \text{ (other than oral/rat)} \tag{E-5}$$

$$F_6 = 2.25 \times 10^{-3} \times (LD_{Lo}, TD_{Lo}) \tag{E-6}$$

$$F_7 = 7.76 \times 10^{-2} \times TLV \text{ (Ref. 2, 3)} \tag{E-7}$$

where $F_1 \ldots F_7$ = hazard factors

LC_{50} = lethal concentration of a substance that will kill 50% of a group of experimental insects or animals

LC_{Lo} = lowest published lethal concentration

TC_{Lo} = lowest published toxic concentration

IC_{50} = concentration of a substance that will immobilize 50% of a group of experimental insects or animals

LD_{50} = lethal dose of a substance that will kill 50% of a group of experimental insects or animals

LD_{Lo} = lowest published lethal dose

TD_{Lo} = lowest published toxic dose

TLV = threshold limit value

The equations were ranked according to evidence from scientific studies and the relative availability of specific toxicity indicators.

Equation E-1 stems from studies of the effluent concentration below which no stress is exerted on aquatic organisms. Considerable evidence now indicates that this concentration is about 0.05 to 0.10 of the 96-hr LC_{50} value (1).

The ideal data base, consisting of information on a large percentage of aquatic species, would show the community response to a range of concentrations during a long time period. Because this information is not available, test organisms are used to represent expected results for other associated organisms. Certain test animals have been investigated intensively because of their importance to man, their availability for research, and their physiological responses to the laboratory environment. In this context, *Daphnia* or other associated organisms indicate the general levels of toxicity to be expected among untested species. If data for *Daphnia* are not available, values for fathead minnows, bluegill, and other types of fish, such as trout, are used.

In the absence of 96-hr LC_{50} data, a 48-hr LC_{50} value may be utilized. This is proposed to be a valid substitution (Equation E-2) since there is often little difference between a 96-hr and 48-hr value. When LC_{50} data are lacking, the method depends on the relative availability of specific toxicity indicators. For this reason other toxicity data (e.g., TC_{Lo}, LC_{Lo}, IC_{50}) were used on occasion.

The most common indicator of toxicity is the LD_{50} (oral/rat) value. The authors of Equation E-4 postulate that the result represents the maximum concentration which has no effect on human health at a consumption rate of 0.002 m^3/day (2 liters/day). Equations E-5 and E-6 were also used in the absence of LD_{50} (oral/rat) data.

In several cases, the only toxicity indicator is a threshold limit value. As proposed, Equation E-7 assumes that the total amount of contaminant in 10 m^3 (average adult respiratory tidal volume in 24 hr) of air may be contained in 0.002 m^3 of drinking water.

Other equations, which were not used, are:

$$F_8 = 4.0 \times 10^{-4} \times LD_{50} \text{ (oral/rat) (Ref. 90)} \qquad \text{(E-8)}$$

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(90) Cleland, J. G., and G. L. Kingsbury, Multimedia Environmental Goals for Environmental Assessment. Contract 68-02-1325, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. (Draft submitted to the EPA by Battelle, January 1977). pp. 1-34.

$$F_9 = 1.38 \times 10^{-2} \times TLV \quad \text{(Ref. 90)} \qquad \text{(E-9)}$$

They do not radically deviate from Equations E-4 or E-7 because the LD_{50} and TLV data are significant to only one figure, and Equations E-4 and E-7 were derived from a regression analysis. The development of Equations E-8 and E-9 is not explained (90), so they were not included as calculation methods.

Most toxicity information is not intended for use in industrial effluent assessment. For instance, practically no information exists for the toxic properties of complex effluents. This methodology attempts to establish a workable, consistent way to formulate potential hazard factors using available data.

Table E-1 is an alphabetic listing by substance name of the following data for each pollutant tested:

- Available toxicological data, test species (when applicable) and references.
- Hazard factors (derived from toxicological data by using Equations E-1 to E-7) and references.
- Hazard factors used in prioritization (F).
- Any necessary comments or clarifications.

Toxicological data are given in milligrams per kilogram unless otherwise stated. LC and LD in the tables refer to LC_{50} and LD_{50} for the hours indicated in parentheses; LC(96), for example. Test species and routes are abbreviated as shown in the list below.

AQTX -- aquatic toxicity
BG -- bluegill
BT -- brook trout
D -- *Daphnia*
FM -- fathead minnow
G -- *Gammarus lacutris* (amphipod)
gpg -- guinea pig
HF -- harlequin fish
hmn -- human
ihl -- inhalation
imp -- implant
ipr -- intraperitoneal
ivg -- intravaginal
ivn -- intravenous
MF -- mosquito fish
mus -- mouse
N -- naids (aquatic young of dragonfly, stonefly)
orl -- oral
rbt -- rabbit
RT -- rainbow trout
scu -- subcutaneous
skn -- skin
wmh -- woman

TABLE E-1. HAZARD FACTORS DEVELOPED FOR USE IN PRIORITIZATION OF STATIONARY WATER POLLUTION SOURCES

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
Abate	LC(96): 0.01 N	91	0.0005	E-1		0.0005
	LC(48): 1.5 BT	91	0.075	E-2		
	LD(orl/rat): 2,000	19	4.5	E-4		
Acenaphthene	TDLo(skn/mus): 600,000	92	1,350	E-6		1,350
Acetaldehyde	LC(96): 53.0 BG	91	2.7	E-1		2.7
	LD(orl/rat): 1,930	92	4.34	E-4		
Acetic acid	LC(96): 75.0 BG	91	3.8	E-1		3.8
	LC(48): 251 MF	93	13	E-2		
	LD(orl/rat): 3,310	92	7.45	E-4		
Acetic anhydride	LD(orl/rat): 1,780	92	4.01	E-4		4.01
Acetone	LC(96): 8,300	91	415	E-1		415
	LD(ipr/mus): 1,297	92	2.92	E-5		
Acetonitrile	LC(96): 1,850	91	92.5	E-1		92.5
	LD(orl/rat): 200	92	0.450	E-4		
Acetophenone	LD(orl/rat): 900	94	2.03	E-4		2.03
Acetylacetone	LD(orl/rat): 1,000	92	2.25	E-4		2.25
Acetyl chloride	LC(96): 10 AQTX	94	0.50	E-1		0.50
Acidity	None		20.0 ($CaCO_3$)		95	20.0 ($CaCO_3$)

(continued)

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(91) Water Quality Criteria Data Book - Volume 3. EPA-18050 GWV, U.S. Environmental Protection Agency, Washington, D.C., May 1971. 526 pp.

(92) The Toxic Substances List--1974. Publication No. HSM 99-73-45, National Institute for Occupational Safety and Health, Rockville, Maryland, June 1974. 904 pp.

(93) Supplement to Development Document: Hazardous Substances Regulations, Section 311 of the Federal Water Pollution Control Act as Amended 1972. EPA-440/9-75-009, (PB 258 514), U.S. Environmental Protection Agency, Washington, D.C., November 1975. 783 pp.

(94) Registry of Toxic Effects of Chemical Substances, 1975 Edition. Publication No. CDC 99-74-92, National Institute for Occupational Safety and Health, Rockville, Maryland, June 1975. 1296 pp.

(95) Quality Criteria for Water. EPA-440/9-76-023, U.S. Environmental Protection Agency, Washington, D.C., July 1976. 501 pp.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factors g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
Acrolein	LC(48): 0.08 S	91	0.004	E-2		0.004
	LD(orl/rat): 46	92	0.104	E-2		
	Partial kill: 0.75 FM	91	0.038	E-3		
Acrylamide	LD(orl/rat): 170	92	0.383	E-4		0.383
Acrylic acid	LD(orl/rat): 340	92	0.765	E-4		0.765
Acrylonitrile	LC(96): 14.3 FM	93	0.72	E-1		0.72
	LC(96): 11.8 BG	93	0.59	E-1		
	LC(48): 16.7 FM	93	0.84	E-2		
	LD(orl/rat): 93	92	0.209	E-4		
Adipic acid	LD(orl/mus): 1,900	94	4.28	E-5		4.28
Adiponitrile	LC(96): 820 FM	93	41	E-1		41
	LC(96): 720 BG	93	36	E-1		
	LC(48): 835 FM	93	42	E-2		
	LD(orl/rat): 105	92	0.236	E-4		
	LDLo(ipr/mus): 40	92	0.09	E-6		
Alachor	LD(orl/rat): 1,800	19	4.05	E-4		4.05
Aldicarb	LD(orl/rat): 0.9	19	0.002	E-4		0.002
Aldrin	LC(96): 0.033 FM	91	0.0017	E-1		
	LC(48): 0.028 D	91	0.0014	E-2		
	LD(orl/rat): 55	19	0.012	E-4		
	None.		0.000003		95	0.000003
Alkalinity	None.		20.0 ($CaCO_3$)		95	20.0 ($CaCO_3$)
Alkylnaphthalenes (methyl)	LDLo(orl/rat): ~5,000[a]	94	11.3	E-5		11.3

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[a]1,6-Dimethylnapthalene	LDLo (orl/rat) mg/kg
1-Methylnapthalene	5,000
2-Methylnapthalene	5,000
Methylnapthalene	5,000
	4,360 - LD_{50}

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
Allyl alcohol	LC(72): 0.75 FM	93	0.04	E-1		0.04
	LD(orl/mus): 96	94	0.22	E-6		
Allyl chloride	LC(96): 24 FM	93	1.2	E-1		1.2
	LC(96): 42 BG	93	2.1	E-1		
	TLV: 3.0 mg/m^3	3	0.23	E-7		
Alpha-pinene ($C_{10}H_{16}$)	LD(orl/rat): 2,570	96	5.78	E-4		5.78
Aluminum chloride	LD(orl/rat): 3,700	92	8.33	E-4		8.33
Aminocarb	LD(orl/rat): 30	92	0.068	E-4		0.068
	LC(24): 0.039 G, ppm	91	0.0020	E-3		
Amitrole	LD(orl/rat): 1,100	92	2.48	E-4		2.48
	IC_{50}: 23 D, ppm	91	1.2	E-3		
Ammonia	LC(96): 8.2 FM	91	0.410	E-1		
	LC(48): 0.41 RT	93	0.02	E-2		
	TLV: 18 mg/m^3	3	1.4	E-7		
	None		0.02		95	0.02
Ammonia-nitrogen (NH_3-N)	None		0.020[b]			0.020
Ammonium acetate	LC(96): 238 MF	93	12	E-1		12
	LC(48): 238 MF	93	12	E-2		
	LD(orl/rat): ~100	94	0.225	E-4		
	LD(ivn/mus): 98	94	0.201	E-5		

(continued)

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[b] MRC personnel.

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(96) The Merck Index, Ninth Edition, M. Windholz, ed. Merck & Company, Inc., Rahway, New Jersey, 1976. 1313 pp.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
Ammonium benzoate^c	LC(48): 17.5 FM	93	0.88	E-2		0.88
	LD(orl/rat): ~100	94	0.225	E-4		
Ammonium citrate^c	LC(48): 17.5 FM	93	0.88	E-2		0.88
	LD(orl/rat): ~100	94	0.225	E-4		
Ammonium formate^c	LC(48): 17.5 FM	93	0.88	E-2		0.88
	LD(orl/rat): ~100	94	0.225	E-4		
	LD(orl/mus): 2,250	94	5.06	E-5		
Ammonium glutamate^d	LC(48): 17.5	93	0.88	E-2		0.88
	LD(orl/rat): ~100	94	0.225	E-4		
	LD(ipr/rat): 1,000	94	2.25	E-5		
Ammonium oxalate^c	LC(48): 17.5 FM	93	0.88	E-2		0.88
	LD(orl/rat): ~100	94	0.225	E-4		
Ammonium tartrate^c	LC(48): 17.5	93	0.88	E-2		0.88
	LD(orl/rat): ~100	94	0.225	E-4		
Ammonium thiocyanate	LC(96): 114 MF	93	5.7	E-1		5.7
	LD(orl/rat): ~100	94	0.225	E-4		
	LDLo(ipr/mus): 500	94	1.13	E-6		
Amyl acetate	LC(96): 65 MF	93	3.3	E-1		3.3
	LC(48): 120 D	93	6.0	E-2		
	LD(orl/rbt): 7,400	94	16.7	E-5		
Aniline	LC(96): 1,000 BG	93	50	E-1		50
	LC(48): 0.4 D	93	0.02	E-2		
	LD(orl/rat): 440	92	0.990	E-4		
Anthracene	LD$_{10}$(animals): 500	96	1.13	E-6		1.13
Antimony	LD(orl/rat): 100	92	0.225	E-4		0.225
Arsenic	TLV: 0.5 mg/m^3	3	0.039	E-7		
	None.		0.050		95	0.050

(continued)

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[c] Toxicity depends on ammonium.

[d] Used value for the monoammonium salt.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factors g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
Asbestos	TDLo(ipr/rat): 280	92	0.630	E-6		0.630
Ascorbic acid	LD(ivn/mus): 518	94	1.17	E-6		1.17
Aspirin	LD(orl/rat): 558	94	1.26	E-4		1.26
Aspon	LD(orl/rat): 450	92	1.01	E-4		1.01
Atrazine	LD(orl/rat): 1,750	92	3.94	E-4		3.94
Azodrin	LD(orl/rat): 21	92	0.047	E-4		0.047
Barium	TLV: 0.5 mg/m^3	3	0.039	E-7		
	None.		1.0		95	1.0
Benefin (Balan)	LD(orl/rat): 790	92	1.78	E-4		1.78
Benomyl (Benlate)	LD(orl/rat): 10,000	19	22.5	E-4		22.5
Bensulide	LD(orl/rat): 770	92	1.73	E-4		1.73
Benz(a)anthracene	TDLo(orl/mus): 4,000	92	9.00	E-6		9.00
Benzene	LC(96): 31.0 FM	91	1.6	E-1		1.6
	LC(48): 395 MF	93	20	E-2		
	LD(orl/rat): 3,400	92	7.65	E-4		
Benzidine	LD(orl/rat): 309	92	0.695	E-4		0.695
Benzo(ghi)perylene	TDLo: 24	92	0.054	E-6		0.054
Benzo(a)pyrene	TDLo(orl/rat): 13	92	0.029	E-6		0.029
Benzoic acid	LC(96): 180 MF	93	9.0	E-1		9.0
	LC(48): 225 MF	93	11	E-2		
	LD(orl/mus): 2,370	92	5.33	E-5		
Benzonitrile[e]	LC(96): 78 FM	93	3.9	E-1		3.9
	LC(48): 78 FM	93	3.9	E-2		
	LD(skn/rbt): 1,200	94	2.7	E-5		
Benzoyl chloride	LC(96): 100 AQTX	94	5.0	E-1		5.0

(continued)

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[e] Hard water conditions.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m³	Eqn.	Ref.	F (hazard factor), g/m³
Benzyl chloride	LD(orl/rat): 1,231	92	2.77	E-4		2.77
Beryllium	TLV: 0.002 mg/m^3 None.	3	0.00016 0.011	E-7	95	0.011
Biacetyl	LD(orl/rat): 1,580	92	3.56	E-4		3.56
Bicarbonate	None.		250		95	250
Biphenyl	LD(orl/rat): 2,180	92	4.905	E-4		4.905
Bis(2-chloromethyl ethyl)ether	LD(orl/rat): 240	92	0.540	E-4		0.540
Bismuth salts	LD(orl/rat): 3,000	97	6.75	E-4		6.75
Bisphenol A	LD(orl/rat): 450	92	1.01	E-4		1.01
Boron	LD(orl/mus): 2,000 None.	92	4.5 0.750	E-5	95	0.750
Bromacil	LD(orl/rat): 3,400	92	7.65	E-4		7.65
Bromide, sodium	LD(orl/rat): 3,500	96	7.88	E-4		7.88
Bromine	TLV: 0.7 mg/m^3	3	0.054	E-7		0.054
Brucine alkaloid	LD(orl/rat): 1	94	0.002	E-4		0.002
Butachlor (machete)	LD(orl/rat): 3,120	19	7.02	E-4		7.02
Butadiene	TLV: 2,200 mg/m^3	3	171	E-7		171
Butane	TLV: 1,450 mg/m^3	3	112.520	E-7		112.520
n-Butanol	LD(orl/rat): 2,510	92	5.648	E-4		5.648
3-Butene nitrile	LD(orl/rat): 115	92	0.259	E-4		0.259
2-Butoxyethanol	LD(orl/rat): 1,480	94	3.33	E-4		3.33
Butyl acetate	LC(48): 44 D TLV: 710 mg/m^3	93 3	2.2 55.096	E-2 E-7		2.2
Butyl acrylate	LD(orl/rat): 3,730	94	8.39	E-4		8.39

(continued)

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(97) Gosselin, R. E., et al. Clinical Toxicology of Commercial Products, Fourth Edition. Williams and Wilkins, Baltimore, Maryland, 1976. 1794 pp.

TABLE E-1 (continued)

Pollutant	Toxicological data		Hazard factor			F (hazard factor),
	mg/kg	Ref.	g/m^3	Eqn.	Ref.	g/m^3
Butylamine	LD(orl/rat): 500	94	1.13	E-4		1.13
Butylate	LD(orl/rat): 4,659	19	10.5	E-4		10.5
Butyraldehyde	LD(orl/rat): 2,490	92	5.603	E-4		5.603
Butyric acid	LC(48): 61.0 D	91	3.1	E-2		3.1
	LD(orl/rat): 2,940	92	6.615	E-4		
Cacodylic acid	LD(orl/rat): 1,350	92	3.04	E-4		3.04
Cadmium	TLV: 0.2 mg/m^3	3	0.016	E-7		
	None.		0.010		95	0.010
Calcium hydroxide	LC(96): 160 MF	93	8.0	E-1		8.0
	LC(48): 220 MF	93	11.0	E-2		
	TLV: 2.0 mg/m^3	3	0.155	E-7		
Calcium oxide[f]	LD(96): 160 MF	93	8.0	E-1		8.0
	LC(48): 220 MF	93	11.0	E-2		
	TLV: 5.0 mg/m^3	3	0.388	E-7		
Caprolactam	LD(orl/rat): 2,140	92	4.815	E-4		4.815
Captan	LD(orl/rat): 480	92	1.08	E-4		1.08
Carbaryl	LC(96): 14.6 FM	91	0.73	E-1		0.73
	LC(48): 0.006 D	91	0.0003	E-2		
	LD(orl/rat): 500	92	1.13	E-4		
Carbofuran	LD(orl/rat): 11	92	0.025	E-4		0.025
Carbon black	TLV: 3.5 mg/m^3	3	0.272	E-7		0.272
Carbon disulfide	LC(48): 135	93	6.75	E-2		6.75
	TLV: 60 mg/m^3	3	4.7	E-7		
Carbon tetrachloride	LD(ipr/mus): 4,620	92	10.395	E-5		10.395
Carbonyl sulfide	LCLo(ihl/mus): 2,900 ppm	92	145.0	E-3		145.0
Carbophenothion	LC(48): 0.225	91	0.01	E-2		0.01

(continued)

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[f] Refer to calcium hydroxide.

TABLE E-1 (continued)

Pollutant	Toxicological data		Hazard factor			F (hazard factor), g/m³
	mg/kg	Ref.	g/m³	Eqn.	Ref.	
Catechol	LD(orl/rat): 3,890	94	8.75	E-4		8.75
CDAA	LD(orl/rat): 700	92	1.58	E-4		1.58
CDEC	LD(orl/rat): 850	92	1.91	E-4		1.91
Chloral hydrate	LD(orl/rat): 285	92	0.641	E-4		0.641
Chloramben	LD(orl/rat): 3,500	92	7.88	E-4		7.88
Chlordane	LC(96): 0.052 FM	91	0.0026	E-1		
	LC(96): 0.022 BG	91	0.0011	E-1		
	LC(48): 0.010 RT	93	0.0005	E-2		
	LD(orl/rat): 570	92	1.28	E-4		
	LC(24): 0.168 G	91	0.0084	E-2		
	None.		0.00001		95	0.00001
Chlorides	None.		250.0		95	250.0
Chlorine	LC(96): 0.1 FM	93	0.005	E-1		
	TLV: 3.0 mg/m^3	3	0.233	E-7		
	None.		0.010		95	0.010
Chloroacetic acid	LD(orl/rat): 76	92	0.171	E-4		0.171
Chlorobenzene	LC(96): 29.0 FM	91	1.45	E-1		1.45
	LD(orl/rat): 2,910	92	6.55	E-4		
Chlorobenzilate	LC(48): 0.710 RT	91	0.036	E-2		0.036
Chloroethers	LD(orl/rat): ~200[g]	92	0.450	E-4		0.450
Chloroform	LD(orl/rat): 300	92	0.675	E-4		0.675
	Partial kill: 100 FM, ppm	91	5.0	E-3		
2-Chloronaphthalene	LD(orl/rat): 2,078	92	4.68	E-4		4.68
Chloroneb	LD(orl/rat): 11,000	19	24.8	E-4		24.8

(continued)

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[g]	LD_{50}(orl/rat)
Bis(chloroethyl)ether	210 mg/kg
Bis(2-chloro-1-methylethyl)ether	240 mg/kg

TABLE E-1 (continued)

Pollutant	Toxicological data		Hazard factor			F (hazard factor), g/m^3
	mg/kg	Ref.	g/m^3	Eqn.	Ref.	
2-Chlorophenol	LD(orl/rat): 670	92	1.508	E-4		1.508
Chloropicrin	TLV: 0.7 mg/m^3	3	0.05	E-7		0.05
Chloroprene	TLV: 90 mg/m^3[h]	3	6.984	E-7		6.984
Chlorosulfonic acid	LC(96): 10 AQTX	94	0.50	E-1		0.50
Chloropropham	LD(orl/rat): 1,200	92	2.70	E-4		2.70
Choline chloride	LD(orl/rat): 3,400	94	7.65	E-4		7.65
Chromium	None.		0.050		95	0.050
cis-9-Octadecanol	LC(96): 1,000	94	50.0	E-1		50.0
cis-2-Pentene[i] (C_5H_{10})	LC_{50}: 40,000 ppm	96	2,000.0	E-3		2,000.0
Citric acid	LD(ipr/mus): 975	92	2.194	E-5		2.194
Cobalt	TLV: 0.1 mg/m^3	3	0.008	E-7		0.008
Copper	None.		1.0		95	1.0
Copper sulfate	LC(96): 0.084 FM	98	0.0042	E-1		0.0042
Coumaphos	LC(96): 18 FM LC(48): 1.0 D	93 93	0.90 0.05	E-1 E-2		0.90
m-Cresol	LC(96): 10 BG LC(48): 24 MF LD(orl/rat): 242	93 93 94	0.50 1.2 0.545	E-1 E-2 E-4		0.50
Cresylic acid	LD(orl/rat): 1,454	94	3.27	E-4		3.27
Crotonaldehyde	LD(orl/rat): 300	94	0.675	E-4		0.675

(continued)

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[h] Skin.

[i] Used the value for 1-pentene.

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(98) Water Quality Criteria Data Book--Volume 5. EPA-18050 HLA, U.S. Environmental Protection Agency, Washington, D.C., September 1973. 537 pp.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m³	Eqn.	Ref.	F (hazard factor), g/m³
Crufomate	LD(orl/rat): 770	92	1.73	E-4		1.73
Cumene	LD(orl/rat): 1,400	92	3.150	E-4		3.150
Cyanide	None.		0.005		95	0.005
Cycloate	LD(orl/rat): 3,160	19	7.11	E-4		7.11
Cyclohexane	LC(96): 30 FM	93	1.500	E-1		1.500
	TLV: 1,050 mg/m^3	3	81.5	E-7		
Cyclohexanol	LD(orl/rat): 2,060	92	4.635	E-4		4.635
Cyclohexanone	LD(orl/rat): 1,620	94	3.65	E-4		3.65
Cyclohexylamine	LD(orl/rat): 710	94	1.60	E-4		1.60
Cyclopentene	LD(orl/rat): 2,140	92	4.815	E-4		4.815
2,4-Dichlorophenoxyacetic acid	LC(96): 0.015 N	91	0.00075	E-1		
	LC(46): 3.7 BG	91	0.19	E-2		
	LC(48): 1.1 RT	91	0.055	E-2		
	LD(orl/rat): 1,200	92	2.70	E-4		
	None.		0.1000		95	0.1000
Dalapon	LC(96): 105 BG	91	5.3	E-1		5.3
	LC(48): 115 BG	91	5.8	E-2		
DDT	LC(96): 0.016 BG	91	0.0008	E-1		
	LC(96): 0.032 FM	91	0.0016	E-1		
	LC(48): 0.00036 D	91	0.000018	E-2		
	LD(orl/rat): 113	92	0.254	E-4		
	None.		0.000001		95	0.000001
Decyl alcohol	LD(orl/rat): 4,720	94	10.6	E-4		10.6
Deet	LD(orl/rat): 200	92	0.450	E-4		0.450
DEF	LC(96): 0.0021 N	91	0.00011	E-1		0.00011
Demeton	LD(orl/rat): 9.0	92	0.020	E-4		
	None.		0.0001		95	0.0001
Diacetone alcohol	LD(orl/rat): 4,000	94	9.00	E-4		9.00

(continued)

TABLE E-1 (continued)

Pollutant	Toxicological data		Hazard factor			F (hazard factor), g/m^3
	mg/kg	Ref.	g/m^3	Eqn.	Ref.	
Diallate	LD(orl/rat): 395	92	0.889	E-4		0.889
Diazinon	LC(96): 0.022 BG	91	0.0011	E-1		0.0011
	LC(48): 0.030 BG	91	0.0015	E-2		
	LD(orl/rat): 134	92	0.302	E-4		
Di-n-butyl phthlate	TDLo(orl/hmn): 140	94	0.315	E-6		0.315
Dicamba	LC(48): 130 BG	91	6.5	E-2		6.5
Dichlofenthion	LD(orl/rat): 250	92	0.563	E-4		0.563
	LC(24): 2.2 HF	91	0.11	E-2		
o-Dichlorobenzene or 1,2-Dichlorobenzene	LD(orl/rat): 500	92	1.125	E-4		1.125
p-Dichlorobenzene	LD(orl/rat): 500	92	1.125	E-4		1.125
2,6-Dichlorobenzonitrile	LD(orl/rat): 2,710	94	6.10	E-4		6.10
1-4-Dichloro-2-butene	LD(orl/rat): 89	92	0.200	E-4		0.200
Dichlorodifluoromethane	TLV: 4,950 mg/m^3	3	384.120	E-7		384.120
Dichloroethane	TDLo(orl/hmn): 0.428	92	0.001	E-6		0.001
Dichloroethylene	LD(orl/rat): 680	92	1.530	E-4		1.530
1,1-Dichloroethylene	LDLo(orl/rat): 400	92	0.900	E-6		0.900
1,2-Dichloroethylene	LD(orl/rat): 770	92	1.733	E-4		1.733
Dichloronaphthoquinone	LD(orl/rat): 1,300	92	2.925	E-4		2.925
2,4-Dichlorophenol	LD(orl/rat): 580	92	1.305	E-4		1.305
2,4-Dichlorophenoxyacetic acid	LD(orl/rat): 375	94	0.844	E-4		0.844
1,2-Dichloropropane 1,3-Dichloropropene > mixture	LD(orl/rat): 140	92	0.315	E-4		0.315
2,3-Dichloropropanol	LD(orl/rat): 90	92	0.20	E-4		0.20
2,2-Dichloropropionic acid	LD(orl/rat): 1,120	92	2.520	E-4		2.520

(continued)

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
Dichlorotetrafluoroethane	1,000 ppm	94	50[j]			50
Dichlorovinyl dimethyl phosphate	LD(orl/rat): 56	92	0.126	E-4		0.126
Dichlorvos	LC(96): 0.001 N	91	0.00005	E-1		0.00005
	LC(48): 0.00007 D	91	0.000004	E-2		
Dicrotophos (Bidrin)	LC(96): 0.43 N	91	0.022	E-1		0.022
	LC(48): 0.600 D	91	0.030	E-2		
	LD(orl/rat): 22	92	0.050	E-4		
Dieldrin	LC(96): 0.016 FM	91	0.00080	E-1		
	LC(96): 0.0079 BG	91	0.00040	E-1		
	LC(48): 0.0034 BG	91	0.00017	E-2		
	LC(48): 0.240 D	91	0.012	E-2		
	LD(orl/rat): 60	92	0.014	E-4		
	None.		0.000003		95	0.000003
Diethylamine	LD(orl/rat): 540	94	1.22	E-4		1.22
Diethylene glycol	LD(orl/hmn): 1,000	94	2.25	E-5		2.25
Diethyl ether	LD(orl/rat): 2,200	92	4.95	E-4		4.95
Di-2-ethylhexyl adipate	LD(ivn/rat): 900	94	2.03	E-5		2.03
Di-2-ethylhexyl phthalate	TDLo(orl/man): 143	94	0.322	E-6		0.322
Diisobutylene	LC(96): 1,000 AQTX	94	50	E-1		50
Diisopropyl ether	500 ppm	93	25[j]			25
Dimerin	LD(orl/rat): 860	93	1.94	E-4		1.94
Dimethoate	LC(96): 0.043 N	91	0.0022	E-1		
	LC(96): 6.0 BG	91	0.30	E-1		0.30
	LC(48): 2.5 D	91	0.13	E-2		
	LC(48): 9.6 BG	91	0.48	E-2		
	LD(orl/rat): 185	92	0.416	E-4		
2,4-D,dimethylamine salt	TDLo(orl/rat): 300	94	0.675	E-6		0.675

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[j] Toxicological value x 0.05.

(continued)

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
2,3-Dimethylbutane	TLV: 360 mg/m^3[k]	3	27.9	E-7		27.9
Dimethyl disulfides	LD(orl/rat): 2,030[l]	92	4.57	E-4		4.57
N,N-Dimethylformamide	LD(orl/rat): 1,500	92	3.38	E-4		3.38
Dimethylfurane	LD(orl/rat): 300	92	0.675	E-4		0.675
2,5-Dimethylfurane	LD(orl/rat): 300	92	0.675	E-4		0.675
Dimethylhydrazine	LD(orl/rat): 122	94	0.275	E-4		0.275
2,3-Dimethylpentane	LC(48): 4,924 MF[m]	91	246	E-2		246
2,4-Dimethylphenol	LD(ipr/mus): 150	92	0.338	E-5		0.338
Dimethyl phthalate	LD(orl/rbt): 4,400	94	9.90	E-5		9.90
Dimethyl sulfide	LD(orl/rat): 3,300	92	7.43	E-4		7.43
Dimethyl terephthalate	LD(orl/rbt): 4,400	94	9.90	E-5		9.90
m-Dinitrobenzene	LDLo(orl/rat): 27	94	0.061	E-6		0.061
Dinitrophenol	LDLo(orl/rat): 30	94	0.068	E-6		0.068
2,3-Dinitrotoluene	LD(orl/rat): 1,122	92	2.53	E-4		2.53
2,4-Dinitrotoluene	LD(orl/rat): 268	92	0.603	E-4		0.603
2,5-Dinitrotoluene	LD(orl/rat): 707	92	1.59	E-4		1.59
2,6-Dinitrotoluene	LD(orl/rat): 177	92	0.398	E-4		0.398
3,4-Dinitrotoluene	LD(orl/rat): 177	92	0.398	E-4		0.398
Dinoseb	LD(orl/rat): 25	92	0.056	E-4		0.056
Dioxathion	LC(48): 0.014 BG LD(orl/rat): 110	91 92	0.0007 0.248	E-2 E-4		0.0007
Diphenyl oxide	LDLo(orl/rat): 4,000	92	9.00	E-6		9.00

(continued)

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[k] Used the value for hexane.

[l] Used the value for diethyl disulfide.

[m] Used the value for heptane.

TABLE E-1 (continued)

Pollutant	Toxicological data		Hazard factor			F (hazard factor),
	mg/kg	Ref.	g/m^3	Eqn.	Ref.	g/m^3
Diquat	LC(96): 130 FM[n]	91	6.5	E-1		6.5
	LC(96): 72 BG	91	3.6	E-1		
	LC(48): 12.3 RT	93	0.62	E-2		
	LD(orl/rat): 231	92	0.520	E-4		
Dissolved oxygen	None.		5.0 (minimum)[o]		95	5.0(minimum)
Disulfoton (Di-Systox)	LC(96): 0.005 N	91	0.00025	E-1		
	LC(96): 3.7 FM	91	0.19	E-1		0.19
	LC(48): 0.04 BG	93	0.002	E-2		
	LD(orl/rat): 10	92	0.02	E-4		
Di-syston	LDLo(orl/rat): 2	94	0.005	E-6		0.005
Diuron	LC(96): 4.0 BG	91	0.20	E-1		0.20
	LC(96): 0.0012 N	91	0.00006	E-1		
	LC(48): 7.4 BG	93	0.37	E-2		
Dodecene (nonlinear)	LC(96): 1,000 AQTX	94	50	E-1		50
Dodecyl alcohol	LD(ipr/rat): 800	94	1.80	E-5		1.80
Dodecylbenzene-hard	LC(96): 10 AQTX	94	0.50	E-1		0.50
Dodecylbenzenesulfonic acid	LC(96): 12 D	93	0.60	E-1		0.60
	LD(orl/rat): 1,260	94	2.84	E-4		
Dodecylbenzenesulfonic acid, calcium salt	LC(96): 12 D	93	0.60	E-1		0.60
Dodecylbenzenesulfonic acid, isopropylamine salt	LC(96): 12 D	93	0.60	E-1		0.60
Dodecylbenzenesulfonic acid, sodium salt	LC(96): 12 D	93	0.60	E-1		0.60
	LD(orl/rat): 1,260	94	2.84	E-4		
Dodecylbenzenesulfonic acid, triethylamine salt	LD(96): 12 D	93	0.60	E-1		0.60

(continued)

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[n] LC_{50}'s obtained in hard water.

[o] The minimum concentration to maintain good fish population.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
Dodecyl mercaptan	LD(orl/rat): 309	92	0.695	E-4		0.695
Dodecylmercapto polyethylene ether glycol	LDLo(orl/rat): 3,360	92	7.56	E-6		7.56
Dursban (chlorpyrifos)	LC(48): 0.020 RT	93	0.001	E-2		0.001
	LD(orl/rat): 145	92	0.326	E-4		
EDTA	LD(orl/rat): 2,000	92	4.50	E-4		4.50
Endosulfan	LC(96): 0.0033 FM	93	0.00017	E-1		
	LC(48): 0.240 D	93	0.012	E-2		
	None.		0.000003		95	0.000003
Endrin	LC(96): 0.0013 FM	93	0.000065	E-1		
	LC(96): 0.0007 BG	93	0.000035	E-1		
	LC(48): 0.0016 BG	93	0.00008	E-2		
	LD(orl/rat): 5	92	0.01	E-4		
	None.		0.000		95	0.0002
Epichlorohydrin	LD(orl/rat): 90	92	0.20	E-4		0.20
EPTC	LD(orl/rat): 1,630	92	3.67	E-4		3.67
Ethanol	LD(orl/gpg): 5,560	92	12.5	E-5		12.5
β-Ethanolamine	LD(orl/rat): 2,100	94	4.73	E-4		4.73
Ethion	LC(96): 2.4 FM	91	0.12	E-1		0.12
	LC(48): 0.23 BG	93	0.012	E-2		
2-Ethoxyethanol	LD(orl/rat): 3,000	92	6.75	E-4		6.75
2-Ethoxyethyl acetate	LD(orl/gpg): 1,910	94	4.30	E-5		4.30
Ethoxylated nonylphenol	LD(orl/rat): 1,620[p]	94	3.65	E-4		3.65
Ethoxylated octylphenol	LD(orl/rat): 4,900[q]	94	11.0	E-4		11.0
Ethyl acetate	TLV: 1,400 mg/m^3	3	108	E-7		
	LD(scu/rat): 5,000	94	11.3	E-5		11.3

(continued)

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[p] Used nonylphenol.

[q] Used octylphenol etoxylate sulfonate.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
Ethyl acrylate	LD(orl/rat): 830	92	1.87	E-4		1.87
Ethylbenzene	LC(96): 29 BG LD(orl/rat): 3,500	93 92	1.5 7.88	E-1 E-4		1.5
Ethyl butyrate	LD(orl/rat): 3,500[r]	94	175	E-4		175
Ethyl chloride	TLV: 2,600 mg/m^3	3	202	E-7		202
Ethylene chloride	LD(orl/rat): 680	92	1.53	E-4		1.53
Ethylenediamine	LD(orl/rat): 760	94	1.71	E-4		1.71
Ethylene dibromide	LD(orl/rat): 140	92	0.315	E-4		0.315
Ethylene dichloride	LD(orl/rat): 680	94	1.53	E-4		1.53
Ethylene glycol	LD(orl/hmn): 1,500	94	3.38	E-5		3.38
Ethylene oxide	LD(orl/rat): 330	92	0.743	E-4		0.743
Ethyl ether	LD(orl/rat): 1,700	94	3.83	E-4		3.83
2-Ethyl-1-hexanol	LD(orl/rat): 3,200	94	7.20	E-4		7.20
2-Ethylhexyl alcohol	LD(orl/rat): 800	92	1.800	E-4		1.800
Ethyl mercaptan	LD(orl/rat): 1,960	92	4.41	E-4		4.41
Fenac	LC(96): 0.06 N LC(48): 22.5 BG (liquid)	91 91	0.0030 1.1	E-1 E-2		0.0030
Fenitrothion	LD(orl/rat): 250	92	0.563	E-4		0.563
Fensulfothion	LD(orl/rat): 2	92	0.005	E-4		0.005
Fenthion	LC(96): 0.0045 N	91	0.00023	E-1		0.00023
Ferbam	LD(orl/rat): 4,000	92	9.00	E-4		9.00
Fluometuron	LD(orl/rat): 89	92	0.20	E-4		0.20
Fluoranthene	LD(orl/rat): 2,000	92	4.50	E-4		4.50
Fluorene-2	TDLo(orl/rat): 15,000	92	33.75	E-6		33.75

(continued)

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[r] Used value for ethyl propionate.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
Fluoride	TLV: 2.5 mg/m^3	3	0.19	E-7		0.19
Fluorine	TLV: 2.0 mg/m^3	3	0.16	E-7		0.16
Folex	LD(orl/rat): 910	92	2.05	E-4		2.05
Fonofos	LD(orl/rat): 8	19	0.02	E-4		0.02
Formaldehyde	LC(48): 2 D	93	0.1	E-2		0.1
	LC(48): 140 BG	91	7.0	E-2		
	LD(orl/rat): 800	92	1.80	E-4		
	LDLo(orl/wmh): 36	92	0.08	E-6		
Formic acid	LC(48): 120 D	93	6.0	E-2		6.0
	LD(orl/rat): 1,210	92	2.72	E-4		
	LC(24): 175 BG	91	8.8	E-3		
Freon 21	1,000 ppm	92	50			50
Fumaric acid	LC(96): 230 MF	93	12	E-1		12
	LC(48): 138 BG	93	6.9	E-2		
	LD(ipr/mus): 200	92	0.450	E-5		
Fumaronitrile	LCLo(ihl/rat): 800 mg/m^3 [s]	94	40	E-3		40
Furan	30,400 ppm	96	1,520[j]			1,520
Gallic acid	LD(orl/rat): 5,000	92	11.3	E-4		11.3
Glycerin-acrolein	LDLo(orl/rat): 5,000[t]	94	11.3	E-6		11.3
Glycerin-allyl alcohol	LD(orl/gpg): 7,750[u]	94	17.4	E-5		17.4

(continued)

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[j] Toxicological value x 0.05.

[s] Used value for 1-chlorofumaronitrile.

[t] Used the value for glyceraldehyde.

[u] Used the value for glycerol.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
Glycerin-epichlorohydrin	LD(orl/rat): 150^{u}	94	0.338	E-4		0.338
Glycerin-tripolyoxypropylene ether	LD(orl/mus): 690	94	1.55	E-5		1.55
Glycerol	LD(orl/gpg): 7,750	94	17.4	E-5		17.4
Guthion (azinphos-methyl)	LC(96): 0.235 FM	91	0.012	E-1		
	LC(48): 0.0002 D	91	0.00001	E-2		
	None.		0.00001		95	0.00001
Hardness	None.		75 to 150^{v}		95	75 to 150
Heptachlor	LC(96): 0.094 FM	91	0.0047	E-1		
	LC(96): 0.019 BG	91	0.00095	E-1		
	LC(48): 0.009 RT	93	0.00045	E-2		
	LD(orl/rat): 40	92	0.09	E-4		
	None.		0.000001		95	0.000001
Heptachlor epoxide	LD(orl/rat): 62	92	0.14	E-4		
	None.		0.00001		95	0.00001
Heptane	LC(48): 4,924 MF	91	250	E-2		250
	TLV: 1,600 mg/m^3	3	124	E-7		
	15,900 ppm	96	795^{j}			
4-Heptene	LC(96): 1,000	94	50	E-1		50
Hexachlorobenzene	LD(orl/rat): 3,500	92	7.88	E-4		7.88
Hexachloronorbornadiene/ hexachloronorbornene	LD(orl/rat): 28^{w}	94	0.063	E-4		0.063
Hexadecyl alcohol	LD(skn/rbt): 2,600	94	5.85	E-5		5.85
Hexamethylenediamine	LC(96): 10	94	0.50	E-1		0.50
Hexamethylenetetramine	LDLo(ipr/mus): 512	94	1.15	E-6		1.15
Hexane	TLV: 360 mg/m^3	3	27.9	E-7		27.9

(continued)

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[j] Toxicological value x 0.05.

[v] Used the value for α-monochlorhydrin.

[w] Moderately hard.

[x] Used value for hexachloronorbornene dimethanol.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
Hexene	LCLo(ihl/rat): 4,000 ppm		200	E-3		200
Hydrochloric acid	LC(96): 3.5 BG LD(ipr/mus): 40	91 92	0.18 0.09	E-1 E-5		0.18
Hydrogen bromide	TLV: 10 mg/m^3	3	0.78	E-7		0.78
Hydrogen chloride	TLV: 7 mg/m^3	3	0.5	E-7		0.5
Hydrogen cyanide	LC(48): 0.07 RT LD(orl/mus): 3.7	91 92	0.004 0.0083	E-2 E-5		0.004
Hydrogen fluoride	TLV: 2 mg/m^3	3	0.2	E-7		0.2
Hydrogen sulfide	TLV: 15 mg/m^3	3	1.2	E-7		1.2
Hydrazine	LD(orl/rat): 60	92	0.14	E-4		0.14
Hydroquinone	LD(orl/rat): 370 Kill(48): 0.278 D	92 91	0.833 0.01[j]	E-4		0.833
Hydroxylamine	LD(scu/mus): 29	94	0.065	E-5		0.065
Hydroxylamine-sulfate	LDLo(ipr/mus): 102	94	0.230	E-6		0.230
Iodine	TLV: 1 mg/m^3	3	0.1	E-7		0.1
Iron oxide	TLV: 5 mg/m^3	3	0.4	E-7		0.4
Iron salts	None.		0.30		95	0.30
Isoamylene (isopentene)	LC(96): 100	94	5.0	E-1		5.0
Isobutanol	LD(orl/rat): 2,460	94	5.54	E-4		5.54
Isobutylaldehyde	LD(orl/rat): 2,810	94	6.32	E-4		6.32
Isobutylene	LC$_{50}$: 40,000 ppm[y]	96	2,000	E-3		2,000

(continued)

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[j] Toxicological value x 0.05.

[y] Used value for 2-ethyl-1-hexene.

TABLE E-1 (continued)

Pollutant	Toxicological data		Hazard factor			F (hazard factor), g/m^3
	mg/kg	Ref.	g/m^3	Eqn.	Ref.	
Isodecyl alcohol	LD(orl/rat): 4,720^{z}	92	10.6	E-4		10.6
Isooctyl alcohol	LD(orl/rat): 1,480	92	3.33	E-4		3.33
Isopentane	LC$_{50}$: 15,900 ppm	96	795	E-3		795
Isophorone	LD(orl/rat): 2,330	94	5.24	E-4		5.24
Isophthalic acid	LD(ipr/mus): 4,200	94	9.45	E-5		9.45
Isoprene	LC(96): 10	94	0.50	E-1		
	LC(96): 75 FM	92	3.8	E-1		3.8
Isopropanol	LDLo(orl/mus): 192	92	0.432	E-6		0.432
Isopropyl acetate	LD(orl/rat): 3,000	92	6.75	E-4		6.75
Isovaleraldehyde	LDLo(orl/rat): 50	92	0.11	E-6		0.11
Kelthane (dicofol)	LC(48): 390 D	91	20	E-2		20
	LD(orl/rat): 575	92	1.29	E-4		
	LC(24): 110 RT	91	5.5	E-3		
Lactic acid	LD(orl/rat): 3,730	92	8.39	E-4		8.39
	Immobilization: 243 D, ppm	91	12^{j}	E-3		
Lead	None.		0.05		95	0.05
Lead arsenate	LC(96): 75 FM	93	3.8	E-1		3.8
	LC(48): 1.4 BG	92	0.07	E-2		
	LD(orl/rat): 100	92	0.225	E-4		
Lindane	LC(96): 0.087 FM	91	0.0044	E-1		
	LC(96): 0.077 BG	91	0.0039	E-1		
	LC(48): 0.075 BG	93	0.0038	E-2		
	None.		0.004		95	0.004
Linear alkyl-benzene	LD(orl/rat): 650^{aa}	94	1.46	E-4		1.46
Linuron	LDLo(orl/rat): 1,000	92	2.25	E-6		2.25

(continued)

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[j] Toxicological value x 0.05.

[z] Used value for decyl alcohol.

[aa] Used linear alkylbenzenesulfonate

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factors g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
Lithium carbonate	LD(orl/dog): 500	92	1.13	E-5		1.13
Lithium chloride	LD(orl/rat): 757	92	1.70	E-4		1.70
Lithium fluoride	LDLo(orl/gpg): 200	92	0.450	E-6		0.450
Lithium perchlorate	LD(orl/mus): 1,150	92	2.59	E-5		2.59
Magnesium	LDLo(orl/dog): 230	92	0.518	E-6		0.518
Malathion	LC(96): 16.0 FM	91	0.80	E-1		
	LC(48): 0.0009 D	93	0.00005	E-2		
	LD(orl/rat): 1,375	92	3.09	E-4		
	None.		0.0001		95	0.0001
Maleic acid	LC(96): 5.0 FM	91	0.25	E-1		0.25
	LC(48): 138 BG	93	6.9	E-2		
	LD(orl/rat): 708	92	1.59	E-4		
Maleic anhydride	LC(48): 240 MF	91	12	E-2		12
	LDLo(orl/rat): 850	92	1.91	E-6		
Malic acid	LDLo(orl/rat): 1,600	92	3.60	E-6		3.60
Maneb	LD(orl/rat): 6,750	19	15.2	E-4		15.2
	TDLo(orl/rat): 64	92	0.14	E-6		
Manganese	None.		0.05		95	0.05
Melamine	LDLo(orl/mus): 1,600	94	3.60	E-6		3.60
Mercury	None.		0.002		95	0.002
Mercury hydroxide	LD(ipr/mus): 17[bb]	92	0.038	E-5		0.038
Mesityl oxide	LD(orl/rat): 1,120	94	2.52	E-4		2.52
Metalkamate (Bux)	LD(orl/rat): 87	92	0.20	E-4		0.20
Methanearsonic acid, calcium salt	LDLo(orl/hmn): 15	94	0.034	E-6		0.034
Methanearsonic acid, disodium salt	LD(orl/rat): 1,800	92	4.05	E-4		4.05

(continued)

[bb] Used the value for methylmercury hydroxide.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
Methanearsonic acid, dodecyl octyl ammonium salt[d]	LD(orl/rat): 750	94	1.69	E-4		1.69
Methanearsonic acid, monosodium salt	LD(orl/rat): 700	92	1.58	E-4		1.58
Methanol	LDLo(orl/hmn): 340	92	0.765	E-6		0.765
Methomyl	LD(orl/rat): 20	92	0.045	E-4		0.045
Methoxychlor	LC(96): 0.035 PM LD(orl/rat): 5,000 None.	91 92	0.0018 11.3 0.10	E-1 E-4	 95	 0.10
2-Methoxyethanol	LD(orl/rat): 2,460	94	5.54	E-4		5.54
Methyl acetate	TLV: 610 mg/m^3 LDLo(orl/rat): 4,800	3 92	47.3 10.8	E-7 E-6		47.3
Methylal	TLV: 3,100 mg/m^3	3	241	E-7		241
Methyl bromide	LD(orl/rat): 60	92	4.66	E-4		4.66
2-Methyl-1-butene	LC_{50}: 40,000 ppm[i]	96	2,000	E-3		2,000
2-Methyl-2-butene	LC_{50}: 40,000 ppm[i]	96	2,000	E-3		2,000
Methyl chloride	LD(orl/rat): 1,800	94	4.05	E-4		4.05
Methylcyclopentane	LC_{50}: 38,000 ppm	97	1,900	E-3		1,900
Methyl-deneton	LD(orl/rat): 40	92	0.090	E-4		0.090
Methylene chloride	LDLo(orl/dog): 3,000	92	6.75	E-6		6.75
4,4'-Methylenedianiline	LD(orl/rat): 347	92	0.781	E-4		0.781
Methyl ethyl acrolein	LD(orl/rat): 26	96	0.06	E-4		0.06
Methyl ethyl ketone	LD(orl/rat): 3,100	92	6.98	E-4		6.98
Methyl ethyl sulfide	LD(orl/rat): 3,300[cc]	92	7.43	E-4		7.43

(continued)

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[d] Used value for the monoammonium salt.

[i] Used the value for 1-pentene.

[cc] Used value for dimethyl sulfide.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factors g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
Methyl formate	TLV: 250 mg/m^3	3	19.4	E-7		19.4
Methyl isobutyl carbinol	LD(orl/rat): 1,410	94	3.17	E-4		3.17
Methyl isobutyl ketone	LD(orl/rat): 2,080	94	4.68	E-4		4.68
Methyl mercaptan	LD(scu/mus): 2.4	94	0.0054	E-5		0.0054
Methyl methacrylate	LC(96): 150 FM	93	7.5	E-1		7.5
	LD(orl/rat): 770	92	1.73	E-4		
Methyl parathion	LC(96): 7.5 FM	93	0.38	E-1		0.38
	LC(96): 8.9 FM	98	0.45	E-1		
	LD(orl/rat): 9	94	0.020	E-4		
2-Methyl pentane	TLV: 360 mg/m^3[k]	3	27.9	E-7		27.9
3-Methyl pentane	TLV: 360 mg/m^3[k]	3	27.9	E-7		27.9
Methyl styrene	LD(orl/mus): 3,160	92	7.11	E-5		7.11
Methyl vinyl ketone	LDLo(ipr/mus): 16	92	0.04	E-6		0.04
Metribuzin	LD(orl/rat): 1,936	19	4.36	E-4		4.36
Mevinphos	LC(96): 0.023 BG	93	0.0012	E-1		0.0012
	LC(48): 0.037 BG	93	0.0019	E-2		
	LD(orl/rat): 4	92	0.009	E-4		
Mirex	LD(orl/rat): 306	19	0.689	E-4		
	None.		0.000001		95	0.000001
Mocap	LD(orl/rat): 80	92	0.18	E-4		0.18
Molinate	LC(96): 0.00034 N	91	0.000017	E-1		0.000017
	LC(48): 0.60 D	91	0.030	E-2		
	LC(48): 0.48 BG	91	0.024	E-2		
Molybdenum trioxide	LD(orl/rat): 125	92	0.281	E-4		0.281
Monoethylamine	LDLo(orl/rat): 400	94	0.90	E-6		0.90
Monosodium glutamate	TDLo(orl/hmn): 43	94	0.097	E-6		0.097

(continued)

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[k] Used the value for hexane.

TABLE E-1 (continued)

Pollutant	Toxicological data		Hazard factor			F (hazard factor), g/m^3
	mg/kg	Ref.	g/m^3	Eqn.	Ref.	
Monuron	LC(96): 40 BG (25% pellet)	91	2.0	E-1		2.0
	LC(48): 16.3 SM	91	0.82	E-2		
Morpholine	LD(orl/rat): 1,050	92	2.36	E-4		2.36
Nabam	LD(orl/rat): 395	92	0.889	E-4		0.889
Naled	LC(96): 0.008 N	91	0.0004	E-1		
	LC(96): 0.18 BG	93	0.0090	E-1		0.0090
	LC(48): 0.0035	93	0.00018	E-2		
Naphtha, coal tar	(ihl/rat): 1,600 ppm	92	80[j]			80
Naphthalene	LC(96): 150 MF	93	7.5	E-1		7.5
	LC(48): 165 MF	93	8.3	E-2		
	LD(orl/rat): 1,780	93	4.01	E-4		
Naphthoquinone	LDLo(orl/mus): 140	92	0.315	E-6		0.315
1-Naphthyl-N-methylcarbamate	LD(orl/rat): 89	92	0.20	E-4		0.20
Neburon	LC(96): 0.7 BG (4% granular)	91	0.04	E-1		0.04
Neopentane	LC_{50}: 15,900 ppm[dd]	97	795	E-3		795
Neopentanoic acid	LDLo(orl/rat): 5,000	94	11.3	E-6		11.3
Nickel	LC(96): 130 x 10^{-3} g/m^3					
	D[ee]	95	0.007	E-1		
	LDLo(orl/gpg): 5	91	0.011	E-6		
	None.		0.0013		95	0.0013
Nitralin	LD(orl/rat): 6,000	19	13.5	E-4		13.5
Nitrate	None.		10		95	10

(continued)

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[j] Toxicological value x 0.05.

[dd] Used the value for isopentane.

[ee] 0.01 of the 96-hr LC_{50} for freshwater and marine aquatic life.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	P (hazard factor), g/m^3
Nitrite	LD(orl/rat): 180[ff]	96	0.405	E-4		
	None.		10		95	10
m-Nitroaniline	LD(orl/rat): 535	94	1.20	E-4		1.20
o-Nitroaniline	LD(orl/rat): 535	94	1.20	E-4		1.20
p-Nitroaniline	LD(orl/rat): 3,249	94	7.31	E-4		7.31
Nitrobenzene	LD(orl/rat): 640	92	1.44	E-4		1.44
o-Nitrochlorobenzene	LD(orl/rat): 288	92	0.648	E-4		0.648
p-Nitrochlorobenzene	LD(orl/rat): 420	92	0.945	E-4		0.945
Nitroglycerine	LDLo(orl/rat): 80	94	0.18	E-6		0.18
3-Nitrophenol	LD(orl/rat): 447	92	1.01	E-4		1.01
m-Nitrophenol	LD(orl/rat): 447	92	1.01	E-4		1.01
o-Nitrophenol	LD(orl/rat): 2,828	92	6.36	E-4		6.36
p-Nitrophenol	LD(orl/rat): 350	92	0.788	E-4		0.788
N-Nitrosodimethylamine	TDLo(orl/rat): 30	92	0.07	E-6		0.07
Nonene (mixed isomers)	LC(96): 1,000 AQTX	94	50	E-1		50
Nonylphenol	LD(orl/rat): 1,620	92	3.65	E-4		3.65
NTA	LD(orl/rat): 1,470	92	3.31	E-4		3.31
Nylon	TDLo(imp/rat): 123	94	0.277	E-6		0.277
Octyl alcohol	LD(orl/mus): 1,790	94	4.03	E-6		4.03
Octyl phenol	LDLo(ipr/mus): 25	94	0.056	E-6		0.056
Octyl phenol ethoxylate sulfonate	LD(orl/rat): 4,900	94	11.0	E-4		11.0
Oil and grease	None.		0.01		95	0.01
Oleic acid	LD(ivn/mus): 230	92	0.518	E-6		0.518

(continued)

[ff] Sodium salt.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	P (hazard factor), g/m^3
Organic nitrogen	None.		0.020[b]			0.020
Orthophosphate	None.		0.100[gg]		95	0.100
Oxalic acid	TLV: 1.0 mg/m^3	3	0.08	E-7		0.08
Paraffins	TLV: 2.0 mg/m^3	3	0.16	E-7		0.16
Paraformaldehyde	LD(orl/rat): 800	94	1.80	E-4		1.80
Parathion	LC(96): 1.4 FM	91	0.070	E-1		
	LC(96): 0.0054 N	91	0.00027	E-1		
	LC(50): 0.0008 D	91	0.00004	E-2		
	LD(orl/rat): 15	92	0.034	E-4		
	None.		0.00004		95	0.00004
PCB's (polychlorinated biphenyls)	LC(96): 0.278 BG	93	0.014	E-1		
	TLV: 1.0 mg/m^3	3	0.08	E-7		
	None.		0.000001		95	0.000001
PCNB	LD(orl/rat): 1,650	91	3.71	E-4		3.71
PCP	LD(orl/rat): 180	96	0.405	E-4		0.405
	LDLo(orl/hmn): 29	92	0.065	E-6		
Pebulate	LD(orl/rat): 1,020	92	2.30	E-4		2.30
Penicillin G-potassium	LD(ivn/mus): 448	94	1.01	E-5		1.01
Penicillin G-procaine	LD(ivn/mus): 70	94	0.16	E-5		0.16
Pentaerythritol	LD(orl/rat): 2,460[hh]	94	5.54	E-4		5.54
Pentane	LD(orl/rat): 1,800	92	140	E-4		140
	LC$_{50}$: 128,200 ppm	96	6,410	E-3		
1-Pentene	LC$_{50}$: 40,000 ppm	96	2,000	E-3		2,000
Perchloroethylene	TLV: 670 mg/m^3	3	52.0	E-7		52.0

(continued)

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[b] MRC personnel.

[gg] Used value for phosphate phosphorus.

[hh] Used pentaerythritol triacrylate.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
pH	None.		5 to 9		95	5 to 9
Phenol	LC(96): 11.5 to 20 BG LD(orl/rat): 414 None.	93 92	0.58 0.932 0.001	E-1 E-4	 95	0.001
Phenyl mercury acetate.	LD(orl/rat): 30	94	0.068	E-4		0.068
Phorate	LD(orl/rat): 1	92	0.002	E-4		0.002
Phosgene	TLV: 0.2 mg/m^3	3	0.02	E-7		0.18[ii]
Phosphamidon	LC(96): 0.15 N	91	0.0075	E-1		0.0075
Phosphate phosphorus	None.		0.10		95	0.10
Phosphorus (elemental)	LC(48): 0.105 BG LDLo(orl/hmn): 1.4 None.	93 92	0.005 0.003 0.001	E-2 E-6	 95	0.001
Phthalate esters	None.		0.003		95	0.003
Phthalic anhydride	LD(orl/rat): 4,020	92	9.05	E-4		9.05
Polyethylene glycol	TDLo(ivg/mus): 420	94	0.945	E-6		0.945
Polypropylene glycol	LD(orl/rat): 419	92	0.943	E-4		0.943
Polyram-Combi	LD(orl/rat): 10,000	19	22.5	E-4		22.5
Polystyrene	TDLo(imp/rat): 19	94	0.043	E-6		0.043
Polysulfide rubber	LDLo(orl/rat): 3,160[jj]	94	7.11	E-6		7.11
Polyvinyl alcohol	TDLo(scu/rat): 2,500	94	5.63	E-6		5.63
Polyvinyl chloride	TDLo(imp/rat): 100	94	0.225	E-6		0.225
POM	TLV: 0.2 mg/m^3	3	0.02	E-7		0.02
Potassium salts	LD(orl/rat): 3,000	97	6.75	E-4		6.75
Prometone	LD(orl/rat): 1,750	92	3.94	E-4		3.94

(continued)

[ii] Decomposes in water to carbon dioxide and hydrochloric acid; the hazard factor (F) for hydrochloric acid is used.

[jj] Used polysulfide, bis(2-hydroxyphenol).

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Toxicological data Ref.	Hazard factor g/m^3	Hazard factor Eqn.	Hazard factor Ref.	F (hazard factor), g/m^3
Propachlor (ramrod)	LD(orl/rat): 710	19	1.60	E-4		1.60
Propane nitrite	LD(orl/rat): 3,000[kk]	99	6.75	E-4		6.75
Propanil	LD(orl/rat): 560	92	1.26	E-4		1.26
Propazine	LD(orl/rat): 5,000	91	11.3	E-4		11.3
Propionaldehyde	LDLo(orl/rat): 800	92	1.80	E-6		1.80
Propionic acid	LC(48): 50 D	93	2.5	E-2		2.5
	LD(orl/rat): 4,290	92	9.65	E-4		
Propyl alcohol	LD(orl/rat): 1,870	92	4.21	E-4		4.21
Propylene glycol	LC(96): 1,000	94	50	E-1		50
Propylene oxide	LD(orl/rat): 1,140	92	2.57	E-4		2.57
Pyrene	LD_{10}(animals): 500	96	1.13	E-6		1.13
Pyrethrins	LC(96): 74 BG	93	3.7	E-1		3.7
	LC(48): 0.070 BG	91	0.0035	E-2		
	LC(48): 0.025 D	91	0.0013	E-2		
Pyridine	LC(48): 944 D	91	47	E-2		47
	LD(orl/rat): 891	92	2.01	E-4		
Pyrogallic acid	LD(orl/rat): 789	94	1.78	E-4		1.78
Pyrrole	LD(scu/mus): 61	92	0.14	E-5		0.14
Quinoline	LD(orl/rat): 460	94	1.04	E-4		1.04
Quinone	LD(orl/rat): 130	92	0.293	E-4		0.293
Resorcinol	LC(48): 56.4 D	91	2.8	E-2		2.8
	LD(orl/rat): 301	93	0.677	E-4		

(continued)

[kk] Used value for amyl nitrite.

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(99) Sax, N. I. Dangerous Properties of Industrial Materials, Third Edition. Reinhold Book Corporation, New York, New York, 1968. 1251 pp.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Hazard factor Eqn.	Hazard factor Ref.	F (hazard factor), g/m^3
Ronnel	LD(orl/rat): 1,740	92	3.92	E-4		3.92
Saccharin	TDLo(orl/rat): 1,820	94	4.10	E-6		4.10
Salicylic acid	LD(orl/rat): 891	94	2.01	E-4		2.01
Selenium	LC(96): 90 E. Coli None.	93	4.5 0.01	E-1	95	0.01
Silver	None.		0.05		95	0.05
Silvex	LC(48): 2.1 D LC(48): 16.6 BG	98 98	0.11 0.83	E-2 E-2		0.11
Simazine	LC(48): 118 BG LC(48): 56 RT	91 91	5.9 2.8	E-1 E-1		5.9
Sodium	None.		250		95	250
Sodium chlorate	LD(orl/rat): 1,200	19	2.70	E-4		2.70
Sodium chloride	LD(orl/rat): 3,000	92	6.75	E-4		6.75
Sodium hydroxide	LC(48): 99 BG TLV: 2.0 mg/m^3	93 3	5.0 0.16	E-2 E-7		5.0
Sorbitol	LC(96): 1,000 AQTX	94	50	E-1		50
Styrene	LC(96): 51 FM LD(orl/rat): 4,920	91 92	2.6 11.1	E-1 E-4		2.6
Sulfate	LDLo(ivn/rbt): 4,470 None.	92	10.1 250	E-6	95	250
Sulfide	None.		0.002		95	0.002
Sulfite, sodium	LD(ipr/rat): 650	92	1.46	E-5		1.46
Sulfolane	LD(orl/rat): 1,540	94	3.47	E-4		3.47
Suspended solids	None.		25[11]		95	25
sym-Trimethylene-trinitramine	LD(orl/rat): 200	94	0.450	E-4		0.450

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[11] For excellent fisheries.

(continued)

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
2,4,5-T	LC(96): 7.2 FM	93	0.36	E-1		0.36
	LC(48): 144 BG	91	7.2	E-2		
	LD(orl/rat): 500	92	1.13	E-4		
	LC(24): 11 BG	91	0.55	E-3		
Talc	LD(orl/rat): 15,000	97	33.8	E-4		33.8
2,3,6-TBA	LC(48): 1,750	91	88	E-2		88
TCA	LD(orl/rat): 3,320	92	7.47	E-4		7.47
TDS (Total Dissolved Solids)	None.		250[mm]		95	250
Tebuthiuron	LD(orl/rat): 644	19	1.45	E-4		1.45
Tellurium	TLV: 0.1 mg/m^3	3	0.01	E-7		0.01
TEPP	LC(96): 1.0 FM	91	0.05	E-1		0.05
	LD(orl/rat): 1.2	92	0.003	E-4		
Terbacil	LD(orl/rat): 6,000	20	13.5	E-4		13.5
Terrazole	LD(orl/hmn): 2,000	92	4.50	E-5		4.50
Tetrachlorobutane	LD(orl/rat): 200[nn]	92	0.450	E-4		0.450
Tetrachloroethane	LD(orl/rat): 200	92	0.450	E-4		0.450
Tetrachloroethylene	TLV: 670 mg/m^3	3	52.0	E-7		52.0
Tetracycline	LD(orl/rat): 807	94	1.82	E-4		1.82
Tetraethyl/tetramethyl lead	LD(orl/rat): 109[oo]	94	0.245	E-4		0.24
Tetraethyl pyrophosphate	LC(96): 1.7 FM	91	0.09	E-1		0.09
	LD(orl/rat): 0.5	92	0.001	E-4		
Thallium	TLV: 0.1 mg/m^3	3	0.01	E-7		0.01

(continued)

[mm] For chlorides and sulfates in domestic water supplies.

[nn] Used the value for tetrachloroethane.

[oo] Used tetramethyl lead value.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Toxicological data Ref.	Hazard factor g/m^3	Hazard factor Eqn.	Hazard factor Ref.	F (hazard factor), g/m^3
Thionazin	LD(orl/rat): 12	19	0.027	E-4		0.027
Tin[pp]	TLV: 0.1 mg/m^3	3	0.01	E-7		0.01
Titanium oxide	15 mg/m^3	94	0.75[j]			0.75
TKN (total Kjeldahl nitrogen)	None.		0.020[b]			0.020
Toluene	LC(96): 44 FM	91	2.2	E-1		2.2
	LC(48): 1,260 MF	93	63	E-2		
	LD(orl/rat): 3,000	92	6.75	E-4		
Toluene-2,4-diamine	LDLo(orl/rat): 500	94	1.13	E-6		1.13
Toluene-2,4-diisocyanate	LD(orl/rat): 10,000	97	22.5	E-4		22.5
o-Toluene sulfonamide	LD(orl/rat): 4,870	92	11.0	E-4		11.0
p-Toluenesulfonic acid	LD(orl/rat): 400	92	0.900	E-4		0.900
Toxaphene	LC(96): 0.0051 FM	91	0.00026	E-1		
	LC(96): 0.0035 BG	91	0.00018	E-1		
	LD(orl/rat): 69	92	0.16	E-4		
	None.		0.005		95	0.005
2,4,5-TP	LD(orl/rat): 650	92	1.46	E-4		
	None.		0.01		95	0.01
trans-2-Pentene	LC_{50}: 40,000 ppm	96	2,000[e]	E-3		2,000
Triallate	LD(orl/rat): 800	92	1.80	E-4		1.80
Trichlorfon	LC(96): 0.51 FM	93	0.003	E-1		0.003
	LC(48): 0.0081 D	93	0.0004	E-2		
	LD(orl/rat): 400	92	0.900	E-4		
1,1,1-Trichloroethane	LD(orl/rbt): 5,660	92	12.7	E-5		12.7
1,1,2-Trichloroethane	LD(orl/rat): 580	92	1.31	E-4		1.31

(continued)

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[b] MRC personnel.

[j] Toxicological value x 0.05.

[pp] Organic.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Eqn.	Ref.	F (hazard factor), g/m^3
Trichloroethylene	LD(orl/rat): 4,920	92	11.1	E-4		11.1
Trichlorofluoromethane	1,000 ppm[qq]	92	50[j]			50
1,2,3-Trichloropropane	LD(orl/rat): 320	94	0.720	E-4		0.720
2,4,5-Trichlorophenol	LD(orl/rat): 820	92	1.85	E-4		1.85
Triethylamine	LD(orl/rat): 460	92	1.04	E-4		1.04
Trifluralin	LC(96): 0.0084 BG	91	0.0004	E-1		0.0004
Trimethylamine	LDLo(ipr/mus): 75	92	0.17	E-6		0.17
TS (total solids)	None.		275		95	275
TSS (total suspended solids)	None.		25		95	25
Turbidity units	None.		1 turbidity unit		95	1 turbidity unit
TVS	None.		5[b]			5
Uranium[rr]	LC(96): 3.7 FM TLV: 0.2 mg/m^3	93 3	0.19 0.02	E-1 E-7		0.19
Urea	LDLo(scu/rbt): 3,000	94	6.75	E-6		6.75
Vanadium[ss]	LC(96): 55 FM TLV: 0.5 mg/m^3	93 3	2.8 0.04	E-1 E-7		2.8
Vernolate	LC(48): 1.1 D LD(orl/rat): 1,630	91 92	0.055 3.67	E-2 E-4		0.055
Vinyl acetate	LC(96): 22 FM LD(orl/rat): 2,920	93 92	1.1 6.57	E-1 E-4		1.1

(continued)

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[b] MRC personnel.

[j] Toxicological value x 0.05.

[qq] Used value for Freon 21.

[rr] Used the value of uranyl acetate.

[ss] Used the value of vanadium pentoxide.

TABLE E-1 (continued)

Pollutant	Toxicological data mg/kg	Ref.	Hazard factor g/m^3	Hazard factor Eqn.	Hazard factor Ref.	F (hazard factor), g/m^3
Vinyl acetylene	LD(orl/rat): 10,000	97	22.5	E-4		22.5
Vinyl bromide	LD(orl/rat): 500	92	1.13	E-4		1.13
Vinyl chloride (chloroethylene)	TLV: 510 mg/m^3	3	39.576	E-7		39.576
Vinylidene chloride	TLV: 40 mg/m^3	3	3.1	E-7		3.1
Vitamin A	TDLo(orl/rat): 55	94	0.12	E-6		0.12
Vitamin B	LD(scu/rat): 5,000	94	11.3	E-5		11.3
Xylene	LC(96): 21 FM	91	1.1	E-1		1.1
	LD(orl/rat): 4,300	92	9.68	E-4		
o-Xylene	LC(96): 21 FM	93	1.1	E-1		1.1
	LDLo(ipr/rat): 1,500	92	3.38	E-6		
Xylenesulfonic acid	LD(ipr/mus): 500	97	1.13	E-5		1.13
Zinc	LC(96): 7.6 FM	93	0.38	E-1		5.0
	None.		5.0		95	
Zineb	LD(orl/rat): 5,200	19	11.7	E-4		11.7
	LD(orl/rat): 55	92	0.12	E-5		
Zirconium	LC(96): 115 FM^{tt}	93	5.8	E-1		5.8
	LC(96): 240 FM^{uu}	93	12	E-1		
	TLV: 5 mg/m^3	3	0.4	E-7		

[tt] Value for zirconium sulfate in hard water.

[uu] Value for zirconium oxychloride in hard water.

GLOSSARY

biodegradability index (BI): Quantitative parameter measuring the ratio of the concentration of polar products and nonpolar products in an organism. Pesticides, for example, are generally nonpolar and will not readily dissolve in a polar solvent (water). Water solubility generally means the compound can be readily metabolized and excreted rather than stored in nonpolar lipids (fats) of organisms and not quickly metabolized.

biochemical oxygen demand (BOD): Measure of the amount of oxygen consumed in the biological processes that break down organic matter in water. Large amounts of organic wastes use up large amounts of dissolved oxygen; thus the greater the degree of pollution, the greater the BOD.

chemical oxygen demand (COD): Measure of the amount of oxygen required to oxidize organic and oxidizable inorganic compounds in water. The COD test, like the BOD test, is used to determine the degree of pollution in an effluent.

dissolved oxygen (DO): Oxygen dissolved in water or wastewater. Adequately dissolved oxygen is necessary to sustain the life of fish and other aquatic organisms and to prevent offensive odors. Low dissolved oxygen concentrations generally are due to discharge of excessive organic solids having high BOD, the result of inadequate waste treatment.

ecological magnification (EM): Quantitative parameter measuring the ratio of the pollutant chemical concentration in the organism and the concentration in water. EM determines the magnification through food chains of the chemical.

immobilization concentration 50 (IC_{50}): Calculated concentration of a substance which is expected to immobilize 50% of an entire population of an experimental animal species.

lethal concentration 50 (LC_{50}): Calculated concentration of a substance in water, exposure to which for 24 hr or less would cause death of 50% of an entire population of an experimental animal species, as determined from the exposure to the substance of a significant number of that population.

lethal concentration low (LC_{Lo}): Lowest concentration of a substance, other than LC_{50}, in water which has been reported to have caused death in animals when they have been exposed for 24 hr or less.

lethal dose 10 (LD_{10}): Calculated dose of a chemical substance which is expected to cause the death of 10% of an entire population of an experimental animal species, as determined from the exposure to the substance by any route other than inhalation of a significant number from that population.

lethal dose 50 (LD_{50}): Calculated dose of a chemical substance which is expected to cause the death of 50% of an entire population of an experimental animal species, as determined from the exposure to the substance by any route other than inhalation of a significant number from that population.

lethal dose low (LD_{Lo}): Lowest dose of a substance, other than LD_{50}, introduced by any route other than inhalation over any given period of time and reported to have caused death in man, or the lowest single dose introduced in one or more divided portions and reported to have caused death in animals.

toxic concentration low (TC_{Lo}): Any concentration of a substance in water to which man or animals have been exposed for any given period of time and for which such exposure has been reported to produce any toxic effect in animals or humans.

toxic dose low (TD_{Lo}): Lowest dose of a substance, as published or made available to publish, introduced by any route other than inhalation over any given period of time and reported to produce any toxic effect in man or to produce carcinogenic, teratogenic, mutagenic, or neoplastic effects in humans or animal.

ultimate biochemical oxygen demand (BOD_L): Total or ultimate first-stage BOD initially present in water at time, t, equals 0. (BOD_5 is approximately 68% of the ultimate BOD.)

CONVERSION FACTORS AND METRIC PREFIXES (100)

CONVERSION FACTORS

To convert from	To	Multiply by
Degree Celsius (°C)	Degree Fahrenheit	$t_{°F} = 1.8\ t_{°C} + 32$
Gram/second (g/s)	Pound/hr	7.937
Kilogram (kg)	Pound-mass (avoirdupois)	2.205
Kilogram (kg)	Ton (short, 2,000 lb mass)	1.102×10^{-3}
Kilogram (kg)	Metric ton	1.000×10^{-3}
Meter^3 (m^3)	Foot^3	3.531×10^{1}
Meter^3 (m^3)	Gallon	2.642×10^{2}
Meter^3 (m^3)	Liters	1.000×10^{3}
Second (s)	Year	3.168×10^{-8}

METRIC PREFIXES

Prefix	Symbol	Multiplication factor	Example
Kilo	k	10^3	1 kg = 1×10^3 grams
Milli	m	10^{-3}	1 mg = 1×10^{-3} gram

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(100) Standard for Metric Practice. ANSI/ASTM Designation: E 380-76$^{\varepsilon}$, IEEE Std 268-1976, American Society for Testing and Materials, Philadelphia, Pennsylvania, February 1976. 37 pp.